A Preliminary Report on Hog Lung-Worms.

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The work covered in this report comprised a series of experiments on the habits and life history of the common hog lung-worms, Metastrongylus apri and Metastrongylus brevivaginatus. This work is still being continued, and its object is three-fold: first, to determine the morphology and habits of these parasites; second, the life history; third, to discover if possible, some practical means of control. The first two points are mainly covered in this report. The third point, and parts of the life cycle are yet to be completed. These experiments are submitted at this time with the hope, that being largely original, they may prove of value to other workers in this field.

The above parasites are of common occurrence in the lungs of Indiana hogs. By different investigators, these same species have been reported from every country where hogs are kept, hence, there is little doubt as to their world-wide distribution. Until recently little work has been done with these worms, especially as regards their habits and life history. Belief is still current that they are of minor economic importance, due no doubt, to their small size and general prevalance. However, it was observed, in the examination of several hundred lungs, that the number and extent of pathogenic lesions varied directly with the number of these parasites present. The very consistent results in this respect, led to the inevitable conclusion that these parasites must be considered of much greater importance in swine economy, than has hitherto been the case.

In the literature on this subject many conflicting terms are used to designate these parasites. Thus Strongylus paradoxus, and Strongylus apri, are two of a number of synonyms for Metastrongylus apri. This form is also confused with another species of common occurrence, namely, Metastrongylus brevivaginatus. In Indiana hogs these species occur in approximately equal number. The chief characteristics by which they can be distinguished are the bursa and spicules of the males. In M. apri, the bursa is bilobate and each lobe is sustained by five costae. The two spicules are very long and slender, and each terminates in a single barb. In M. brevivaginatus, the bursa is less campanulate, and each spicule terminates in two hooks. These spicules are much shorter, averaging only 1.25 mm. in length. The body of this species is also longer and stouter than is the case in M. apri. In these experiments M. apri is chiefly considered, although, in general, such conclusions as are drawn can apply to both species.

The most recent classification ascribed to these parasites is the following:

1. Phylum; Nemathelminthes.
2. Class; Nematoda.
3. Family; Strongylidae.

4. Sub-family; Metastrongylidae.
5. Genus; Metastrongylus.
6. Species; M. apri.
7. M. brevivaginatus.

Description.

M. apri: Cylindrical, unsegmented worms; body long and slender; buccal capsule absent or slightly developed; mouth with six lips; dorsal and externodorsal rays slender, the other thick; postero-lateral ray reduced or absent; females often show a dark hair line throughout their length; cuticle transversely striate. Male: 12 to 17 mm., average length, 16 mm.; spicules very long (about 4 mm.), and each terminates in a single barb; bursa deeply bilobate, opens laterally; five costae in each lobe; spicules segmented, cylindrical, capable of being coiled up within the bursa or of being withdrawn into the body cavity; dark brown, reticular tubes of chitin; fleshy portion consists of a membrane which is attached by a bulb like expansion to the seminal vesicle. Female: 2 to 4 cm.; vagina about 2 mm. in length; vulva close to anus, and on a slight eminence in front of it. Eggs contain living embryos coiled within them, and range in length from .05 mm. to .08 mm. The width averages .02 mm. less than the length; tail of female terminates in a short horn-like process; embryos when liberated measure .22 to .25 mm. in length, and .01 to .012 mm. in thickness.

M. brevivaginatus: The same general description applies to this species as to M. apri. Male: 15 to 20 mm. long; spicules 1 to 1.5 mm. long; body and bursa larger, stouter and more conspicuous, than in preceding. Females: 3 to 5 cm. long; eggs .07 to .10 mm. long and .05 to .08 mm. wide; larvae somewhat larger than those of M. apri.

Morphology.

When viewed under a low power objective, the structure of these parasites is found to be relatively simple. In both sexes there is a dark, well defined, digestive tract traversing the entire length of the individual. This tract communicates with the mouth by means of a muscular, conoid esophagus, and terminates in a ventral anus near the posterior end of the body. Worms that are full grown show the body cavity to be almost completely filled with enlarged and convoluted reproductive organs. These, together with the alimentary tract, so completely fill the body cavity that there remain only here and there small irregular spaces. In the female the oviduct becomes continuous with the uterus, a short distance behind the esophagus. It then pursues a course parallel to the intestine, until it terminates in the vulva on a slight prominence in front of the anus. The reproductive organs of the male consist likewise of a single tube. However, this tube is not bent upon itself, as is the case in the female, but is single and tapering, and constricts to form the testicles and the seminal vesicle. To the terminus of this last are attached the two spicules, which function in copulation. The body of the female terminates in a blunt horn-like projection, that of the male in a rather complicated, membranous, clasping apparatus. During copulation the male grasps the female with this structure, and impregnates her by inserting the spicules already mentioned, into any region of her body, so that they penetrate to the uterus. Here the sperms are discharged and fertilization takes place.

The females are viviparous and produce hundreds of young. Within the uterus the eggs may be found in all stages of development. This development becomes more and more complete as the eggs approach the oviduct, till finally, when this last is reached, full grown, active larvae may be seen coiled within the egg capsules. The eggs are oval in shape and possessed of at least two membranes. On the outside there is a thick envelope of a gelatinous nature, which is very sticky, and which adheres readily to whatever surface it touches. Around the body of the embryo there is another thin, protective membrane, within which the embryo may often be found intact, even after the removal of the outer gelatinous coat. The thin, transparent, membranes which surround these eggs, together with their ease of procurement, should make them ideal for the study of karyokineses, and kindred biological investigations.

The body wall of these parasites shows many peculiarities. Enclosing the body contents is a transversely striated, muscular layer, somewhat thickened at the two extremities. In the male, well defined, oblique striations occur in the region of the bursa. The costae which support the bursal membrane are projections of this same muscle layer. On the outside there are several layers of very thin cornein, which are transparent and easily permeable to gases and liquids. When an adult specimen is placed in distilled water, the following changes may be observed: In a few minutes the outer layer of cornein separates from the muscle layer in blister-like swellings all over the body. These blisters are very transparent and easily overlooked. When touched with a needle, they at once collapsed, showing that they are formed of a membrane which encloses a fluid of high osmotic pressure. As this interchange of liquids continues, the specimen grows tense and turgid, until it finally bursts open along the median ventral line. The body contents are then forcibly ejected by the contraction of the longitudinal muscle fibres in the body wall. The rupture thus begun continues throughout the whole length until the worm is entirely everted. In this condition the body wall looks like an undulated band or ribbon, and is shrunk to about one-fifth of its original length. Specimens prepared in this manner are easy to study as the internal organs suffer little injury. By this means the eggs are discharged in great abundance wherever suitable conditions are found.

The characteristics shown by these worms suggests at once that very exact environmental conditions are necessary for their development. In this phylum of parasitic roundworms, respiration is seemingly effected through the dermal surface, for the adults, at least, show very quick responses to density changes in surrounding liquids. Indeed, so delicate is this adjustment, that a specimen of Trichinella spiralis (which had been kept in strong formaldehyde solution for three years) exhibited very life-like movements, when placed into a drop of water. Other specimens, known to be dead, acted in like manner when the solution in which they were kept, was placed upon a slide, and allowed to evaporate. These experiments would tend to prove that the body wall plays an important part in the metabolic functions of these parasites. This fact is important, because it may offer ultimately a means of control. For example, Kroening reports very favorable results in the treatment of sheep lung-worms, by injecting a 1 per cent solution of carbolic acid into the trachea. The ready absorption of volatile liquids or gases by these parasites, would offer a ready explanation for his results. Further experiments are, however, needed along this line, especially as regards administering, and the standardization of lethal doses of the antiseptics used.

Distribution.

Believing that a knowledge of the approximate frequency and distribution of these parasites would shed some light upon their life history, a systematic count was kept to determine these facts. Table 1 shows the range and distribution for an entire year. The degrees of infestation of the different lots of hogs examined, have been reduced to percentages, and from these last the accompanying chart was constructed. Turning now to the chart we see two points of rather light infestation. These are due to the fact that the hogs were all over a year old. These instances tend to uphold the results of other investi-

TABLE 1.

Prevalence of M. apri in Local Hogs.

Date Examined	Hogs Examined	Hogs Infected	% of Infestation
1920			
March 15	11	4	.363
March 16	31	12	.387
April 3	19	3	.157
April 10	37	17	.450
April 24	52	23	.442
May 4	28	4	.142
Sept. 13	62	48	.774
Sept. 20	47	34	.723
Sept. 27	45	35	.777
Oct. 4	32	24	.750
Oct. 18	39	28	.718
Oct. 25	29	21	.724
Nov. 1	25	17	.680
Nov. 8	62	44	.709
Nov. 22	53	38	.716
Nov. 29	45	32	.711
Dec. 6	42	29	.690
Dec. 13	28	18	.642
Dec. 20	35	21	.600
1921			
Jan. 3	43	27	.627
Jan. 10	19	10	.526
Jan. 17	30	17	.566
Jan. 31	27	15	.555
Feb. 14	42	17	.404
Feb. 21	57	26	.456
Feb. 28	74	28	.378
March 7	62	27	.435
March 14	83	32	.385
March 21	28	9	.350
March 28	35	10	.314
April 11	62	29	.467
April 18	60	24	.400
May 2	74	35	.472
May 16	50	22	.440

Total number of hogs examined: 1458.
Number of affected hogs: 780.
Average percent of affected hogs: .534.

gators, namely, that older hogs or pigs are more resistant to these worms. If we omit these digressions, our curve will then show a decided symmetry. March was found to be the month of least infection, and this is doubtless due to their getting rid of parasites during the winter months, and not acquiring subsequent infection. The dotted line represents a period during which no observations were made. Again, the maximum infestation is found to occur during the summer and fall months. The percent of affected hogs diminishes gradually during the winter months, until it again reaches the lowest level in March. In the succeeding months of April and May, a rather sharp rise may be noted, and this in a measure corresponds to the warm rainy weather of these two months. It would seem therefore, that

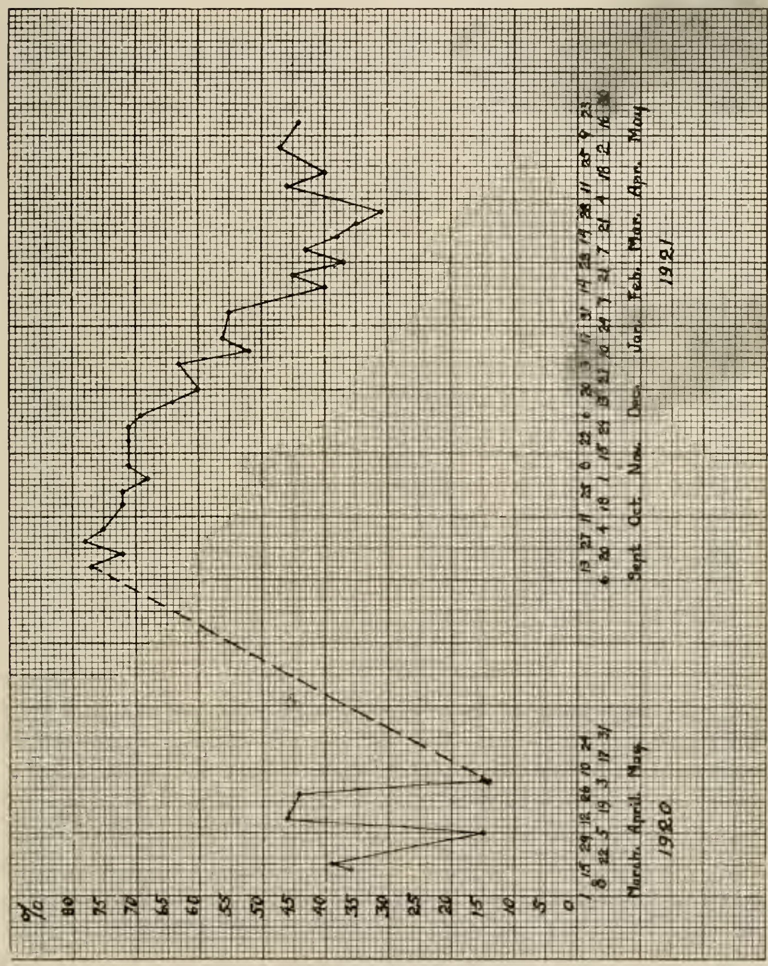

CHART FOR TABLE I.

warmth and moisture are essential environmental conditions for the development of these worms. The total number of hogs examined was 1,458. Of these 780 were found affected with lung-worms, which gives an average of 53 per cent for the entire year.

FREQUENCY.

In this experiment, the lungs of four hogs were examined, which showed average infestation. These hogs are indicated respectively as A, B, C and D in table 2. In the lungs of hog A, three lesions were found; two in the right and one in the left lung. These lesions were carefully excised and dissected in physiological salt solution, in which the worms were counted. Like procedure was followed in the case of the other lesions, and the numerical results obtained are shown in the table. Certain facts that are thus brought out might be emphasized: first, the size of the lesion is but a rough index of the number of worms it contains; second, the right lungs are more often affected than are the corresponding left lungs; third, the ratio of males to females is approximately one-half.

TABLE 2.

Lung Worm Count in Affected Hogs.

Hog	Lung	Lesion	Size of Affected Area	Females	Males	% of Males
	Right	1	31 X 17 mm.	18	10	.55
A	"	2	35 X 18 mm.	62	22	.34
	Left	3	37 X 20 mm.	47	27	.57
B	"	4	40 X 35 mm.	32	18	.56
	Right	5	30 X 15 mm.	57	33	.56
C	"	6	35 X 22 mm.	28	17	.75
	Left	7	34 X 20 mm.	42	24	.56
	"	8	27 X 15 mm.	51	20	.39
D	Right	9	36 X 19 mm.	54	25	.46
	"	10	18 X 12 mm.	12	5	.41

Hog A contained 186 worms.
Hog B contained 140 worms.
Hog C contained 111 worms.
Hog D D contained 167 worms.
Average of males 51%.
In this count no attempt was made to separate the species of lung-worms.

DIAGNOSTIC SYMPTOMS.

Unless they occur in very large number, lung-worms give little indication of their presence. The first symptom is a dry, husky cough, accompanied with an arching of the back. Frequently, there is a profuse discharge from the nostrils and eyes, and the membranes of these are pale. Young pigs that harbor this parasite show a general unthriftiness, anaemia, and looseness of the skin. In extreme cases, vomiting and diarrhoea may also occur. It should be borne in mind however, that all these symptoms are obscure and of too general application to be of much value. For example, a post-mortem examination of several pigs, that had evinced typical lung-worm symptoms, brought to light a heavy infestation of Ascaris suilla. These worms were present in such numbers that they practically filled up the stomachs and intestines of all affected individuals. Superficial diagnosis should therefore be always followed by a post-mortem or microscopic examination.

The typical appearance of a lung affected with these parasites will show the initial lesions occurring at the very posterior tip. These lesions are gray in color, and have a solid appearance and feeling. A sharp demarkation also exists between the healthy and affected portions. These last rise prominently against the general surface, and are due to the clogging up of air tubes by the bodies of the worms and the debris they produce. Adult worms feed on blood and lymph by puncturing the walls of blood vessels, thus causing an acute inflammation. The eggs and larvae produce a diffuse pneumonia characterized by a dry puffiness of lung tissue. In old hogs, extensive, watery tumors occur, in which remnants of dead worms can be found. Small nodules, very characteristic of true tubercles, are also present.

One noticeable feature of these examinations was the common occurrence of bacterial lesions associated with the presence of these parasites. Probably these worms do not carry infection themselves, but the watery tumors which they produce undoubtedly make excellent culture media for any bacteria that chance to find their way into the lungs. In the hundreds of cases that were examined, secondary infections of this nature were of frequent occurrence. Lung-worms may thus be an important factor in causing disease.

Life History.

The general paucity of exact information in the field of parasitology is made very apparent when we attempt to find some concrete statements regarding the parasite in question. Until quite recently, nothing was known of its life history. The following report, copied from California Experiment Station circular 148, presents our most authentic knowledge of this subject.

"Early in our investigations we observed that the embryos found in the lungs were of two kinds. Our first thought was that these might be embryos of two different species of lung-worms, but this was discounted by the fact that we could find but one species of adults in the lungs. That the difference might be due to sex was rejected owing to the fact that the types differed not only in shape and structure, but also in their movements, location and habits. Thus the theory gained belief that these two types were designed to maintain a free-living and a parasitic generation. This belief was confirmed by Doctor von Linden of the University of Bonn, who found that in the mucus of the trachea and of the space behind the nose there were slim, strong-moving embryos that were capable of living outside the body. In the lungs the embryos were short, thick, slow moving and unable to live outside the body. Dr. von Linden found that if slim, strongly moving larvae are placed on moistened earth they continue their development, and she has been able to raise eleven successive free-living generations in this way.

"Dr. von Linden believes that the embryos destined to reproduce the free-living generations, work their way up to the trachea and are swallowed and excreted from the body with the faeces. The embryos then moult and withdraw within their skins, which form a sort of cyst, protecting the larvae from extremes of heat or cold and dryness until conditions are suitable to their growth. Under favorable conditions the second generation of worms appears in from four to six weeks and further generations continue to appear at this interval for about four months. This period of increase is generally followed by a standstill of about three months when the increase again starts. The thick, slow moving embryos die almost immediately when placed outside the body."

In addition to repeating the above experiments two other alternatives were tried, namely, to determine the possibility of some intermediate host, and to see to what extent these parasites develop within the soil.

Theory of Free-living Generations.

The common occurrence and wide distribution of these worms suggests a comparatively simple life history. Before proceeding further, it might be well to emphasize the fact that much confusion still exists between these species of lung-worms. This difficulty is, however, more nominal than real, because even with the unaided eye both species of the males at least, can be readily distinguished. By plunging a mass of these worms into a 30 per cent solution of alcohol in a watch glass, and inspecting them against a black background, there is little difficulty in separating the two species. The males of M. apri are more transparent, more tightly coiled and slender, than is the case with M. brevivaginatus. The females of the former species are also more slender and average about 4 cm. in length. The following averages (obtained by measuring one hundred males of each species) give first the body length, and second, the length of spicules.

	M. apri.	M. brevivaginatus
Length of body..........................	14.16 mm.	18.50 mm.
Lengths of spicules....................	3.80 mm.	1.25 mm.

An examination of twenty lesions from as many different hogs, showed the presence of both species of lung-worms in thirteen cases. Of the remaining seven lesions, five contained M. apri, and three contained only M. brevivaginatus. These results would indicate that this last species is much more common than is generally supposed. Experimental evidence seems to indicate that most females over 4 cm. in length, and the larger eggs (mentioned under description) belong to this species.

Attempts to duplicate the work of Dr. von Linden were in the main unsuccessful. Most of the points she mentioned were repeated, but the conclusions did not always coincide. The following tabulation gives the results obtained, together with their probable interpretation.

Structural differences were invariably found due to sex, especially if the larvae were well advanced in their development. This differentiation began to appear in the second week of growth when the larvae were grown in soil cultures. Besides this anatomical difference, a difference in size was commonly observed. These two distinct types could always be traced to the presence of two species of lung-worms. If, for example, females over 4 cm. were placed in sterile soil, the resulting larvae were always of two kinds. The first was a slim, active form, and the other a rather stout, sluggish form. In this last, ovaries were clearly distinguished in the second week of growth. The larvae within each group were consistently alike, hence their structural differences could only be due to sex. In soil cultures where no effort was made to separate the females on the basis of length, two kinds of larvae were also found; namely, the slim, and the active forms. However, each of these types could be further divided into two groups, which were identical in every respect except size. The presence of these larger larvae could be best explained on the basis that they were the young of M. brevivaginatus.

Active larvae were found in scrapings from the sinuses of the head, the trachea, and in the mucous discharges from the nose. These more active forms were found to be due simply to differences in the stage of development. Experiments have shown that the larvae of lung-worms remain sluggish for several days after they are hatched, during which time important morphological changes occur.

Attempts to raise the free-living generations were unsuccessful. However, when the proper environmental conditions were provided, there was little difficulty in growing larvae taken directly from the lungs. Such larvae grew actively for a period of four weeks, after which time no growth took place but they continued to live indefinitely. These results do not agree with the statement made by Dr. von Linden and others, that the embryos taken from the lung die almost immediately when placed outside the body. It was found that young larvae are very susceptible to moisture and temperature changes, to bacteria and decomposition products, and to proper aerobic conditions. No difficulty was experienced in keeping lung-worm larvae for several days in physiological salt solution, provided this solution was changed daily, and thoroughly aerated.

Theory of Intermediate Hosts.

In conducting this series of experiments, such animals were used as are commonly found in hog runs and wallows, and which might readily be a source of infection to the hog. Table 3 shows in tabular form the animals with which experiments were conducted and their attendant results.

Most of the flies and lice were caught upon the bodies of dead hogs. A count was kept of each species, to find if possible, the per cent of infected individuals. Specimens were examined by tearing them to pieces in salt solution, and dissecting the contents under a binocular microscope. No affected individuals were found.

Attempts to infect the Ostracoda and Cyclops were made by placing them in a beaker of water, into which were also put a large number of lung-worm larvae. These were left in contact for ten days, during which time daily examinations were made to determine any occurrence of parasitism. The results were consistently negative. Examination of these crustacea was facilitated by first dissolving out the

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calcareous skeletons with HCL, and then compressing them between two slides.

Earthworms, from which most of the intestinal contents had been squeezed out, were placed into soil cultures containing larvae in different stages of development. These were examined at varying intervals, ranging from one to five weeks. The method of doing this was to place a cleaned individual into salt solution, in which it was cut open and the intestinal contents examined. Small pieces of the worm itself were next compressed between two slides and observed under the microscope. Among the contents of the intestine, many lung larvae and larval skins were found. However, the larvae were all dead and seemingly had undergone digestion. Parasitism of the worms themselves was found in two individuals. These showed, imbedded in the tissues, roundworms very similar to the lung-worm larvae in question. Remembering, however, that all were equally exposed to infection and that only these two specimens were found parasitized, any conclusions derived from this experiment must necessarily be unreliable. Such parasites as were found could have been acquired before the worms were placed into the soil cultures.

In conducting the experiments with rats, four individuals were used. Two of these were fed lesions containing lung-worms at intervals of one week apart for a period of four weeks. The other two rats were fed larvae in advanced stages of development, and at approximately the same intervals, for a period of ten weeks. After one month the first two rats were killed and found free from infection. The other pair of rats was killed three months after the first, and two weeks after the last feeding. These had very typical verminiferous lesions in both posterior lobes of the lungs. When these lesions were examined, numerous dead larvae and cast skins were found within them. No living larvae were found.

An examination of the rat faeces showed that most larvae were excreted within the first 24 hours. In faeces of the first pair of rats no larvae could be found after the second day of feeding. In the case of the other two rats, the larvae persisted for four days. A large portion of these last seemed to have escaped digestion, but no living larvae were found.

Blood samples of these rats were taken at different times, but gave negative results.

TABLE 3.

Experiments with Intermediate Hosts.

Species	Number Examined	Results	Completed
Colliphora erythrocephala (Blue-bottle Fly)	35	Negative	1920 Sept. 22
Musca domestica (Common House Fly)	67	"	Sept. 27
Haematopinus suis (Hog Louse)	47	"	Sept. 28
Cypris candida	19	"	Oct. 9
Cyclops	22	"	Oct. 11
Earthworms	17	?	Oct. 27
White Rats	4	Positive	May 9

It would appear from these experiments that M. apri and M. brevivaginatus have no intermediate hosts, but that active, growing larvae may occasionally invade the lungs of another animal than the hog. In such a case, however, they are unable to continue their development. An exception might be cited in the case of the human host; for several cases are on record where worms, seemingly identical with those of the hog, have been found in human lungs.

Theory of Partial Development in the Soil.

Analyzing the facts thus far considered, it would appear that these parasites spend a part of their development within the soil. To grow these worms, small wooden boxes were used parafined on both surfaces. Different kinds of soils were found to give different results. The optimum soil types were, first, a humus to which some sand had been added, and second, soil scrapings from the bottom of an old manure pile. Neutral or slightly alkaline soils gave the best results. It appears that young larvae feed within the soil, for they made no appreciable growth in the sterile plots until such time as seeds were planted and had begun to sprout. In this regard oats and beans gave satisfactory results, and they served moreover, as excellent indices in the control of moisture. Check experiments were in all cases conducted with soil sterilized under a pressure of fifteen pounds of steam for one hour.

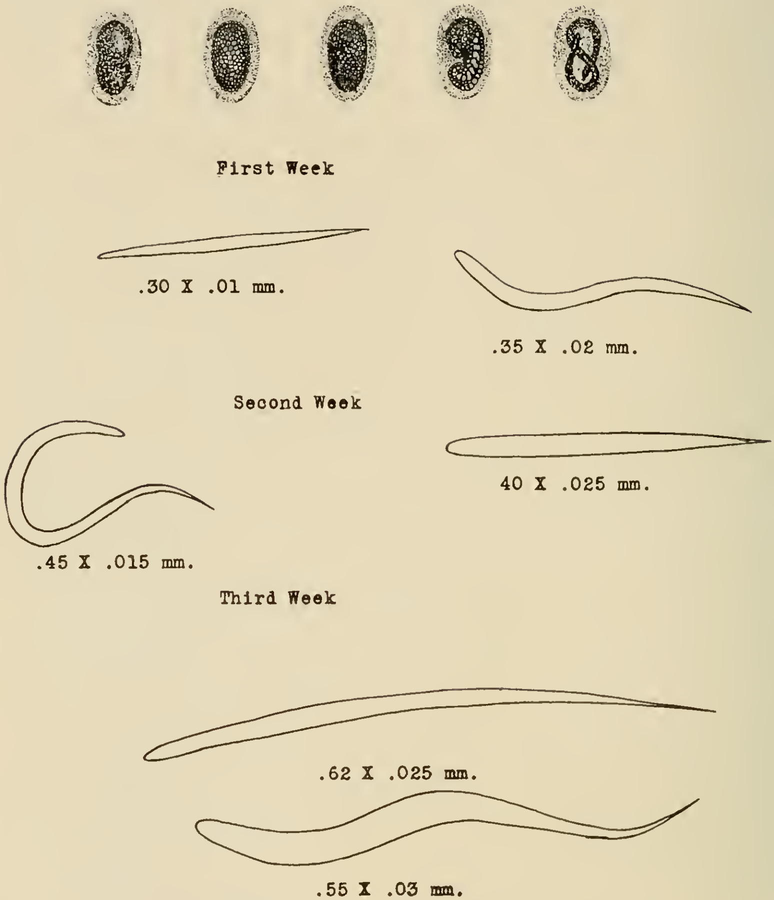
Besides the soil types mentioned above, moisture and temperature were found to be factors of prime importance. The temperatures that gave the best results and at which the larvae were the most active, ranged from 35 to 40 degrees Centigrade, and preferably within the upper limits of this range. The moisture requirement is peculiar and must be very exact. As these parasites require an abundance of oxygen, all experiments involving them had to take this factor into consideration. Too much and too little moisture were both detrimental. The former excluded the air from the soil, and the latter condition inhibited motion and proper metabolic development. The larvae grew most rapidly in soils that were damp and porous, and that contained much organic matter. Moisture requirements were best controlled by means of vegetation growing within the plots. Newly hatched larvae are especially succeptible to these changes, and they are readily killed if the soil is allowed to dry out.

In their development these larvae showed many marked peculiarities. Under ideal conditions they increased rapidly in size during a period of four weeks. During this time the digestive tract and sex organs become well defined. The bodies of both sexes terminate in a spine-like process, which is much longer in the males. These last are also more slender and active than the females. Motion is effected by side to side contractions of the body, which cause the worm to move rapidly along especially in a media of semi-fluid consistency. Plate I shows the appearance of these larvae during different stages of growth.

A decided metabolic difference exists between partly developed larvae and those which are just hatched. Experiments conducted with different digestive ferments, such as bile, saliva, liver extract, etc., showed that the former larvae are much more resistant to the action of

PLATE 1

DEVELOPMENT OF METASTRONGYLUS APRI



DEVELOPMENT OF METASTRONGYLUS APRI

The eggs are intended to show the various developmental stages.
The larvae show actual measurements, and were drawn by means of the camera lucida.

these enzymes. Thus, two-weeks-old larvae individuals were not digested when left in these ferments for 24 hours. On the other hand, young embryos were all killed after five hours, unless they were protected by the egg membranes. Likewise, when subject to weak antiseptics of different kinds, the same general results were obtained. Freezing seems to kill at all stages of development, but experiments with dessication have shown that two-weeks-old larvae can withstand prolonged drying out without injury. Such larvae were revived three months

TABLE 4.

To Show the Rate of Growth of Metastrongylus apri in Millimeters, Attained Within the Soil.

First Week		Second Week	
Length	Width	Length	Width
.32	.015	.42	.011
.33	.015	.46	.015
.30	.012	.40	.010
.35	.016	.48	.020
.31	.014	.49	.021
.30	.012	.50	.025
.29	.011	.42	.011
.32	.015	.48	.020
.32	.012	.39	.018
.35	.015	.52	.025
Third Week		**Fourth Week**	
Length	Width	Length	Width
.55	.020	.63	.028
.50	.018	.72	.037
.60	.035	.74	.054
.65	.040	.60	.035
.50	.018	.67	.025
.65	.035	.70	.035
.63	.035	.72	.045
.59	.020	.69	.035
.57	.018	.74	.055
.62	.032	.65	.040

The above measurements are random selections of male and female larvae of both species. They attained their maximum size by the end of the fourth week, after which they began to die off. However they continued to persist indefinitely.

after they had been permitted to dry out in the soil at room temperature, by placing them in water. Incidentally it was noticed that many samples of these same larvae continued to live after they had remained in weak chloral hydrate solution for three months. Evidently, profound morphological changes occur during this time, which enable these parasites to withstand unfavorable environmental conditions.

Six weeks after this period of rapid growth, the larvae still remained active, but did not increase in size. Numerous cast skins and dead larvae began to appear. It is certain that moulting took place, but the actual number of these moults could not be determined. Unfavorable conditions seem to prolong the life cycle of these parasites, for they encyst and remain inactive, until such time as favorable conditions return. Apparently these larvae die off gradually if they do not find a suitable host. In the laboratory, they have persisted in this manner for almost a year.

There are also good grounds for belief that these worms may develop directly within the lungs. Since, in a majority of cases, the initial lesion begins at the very posterior tip of the lung, and often contains great numbers of worms, the theory is hardly tenable that all these worms entered as individual larvae, and all migrated to this particular area of the lung. Most lesions that were examined, were found to contain these strongylus in all stages of development. The adult specimens lay massed together at the terminal end of a bronchus, while the more active larvae, equivalent in size to those which had attained a week's growth within the soil, could be found in the mucous of the entire respiratory tract. Where two or more lesions occurred in a single lung, one was invariably found that was older than the rest. Such a typical old lesion was hard and watery to the touch, and when cut open, was found to contain numerous granules among which were the disintegrated bodies of adult worms. The suggestive thing is that a lesion of this kind always occurred at the lowest part of the lung, and the secondary lesions were scattered along branches of the same bronchus in which the older lesion was found. These conditions could be explained on the theory that the adult worms secrete toxic substances which cause an accumulation of lymph, that eventually kills them. The partly developed larvae, being active and resistant, make their way along the course of the bronchus until they lodge at the terminus of one of its branches. Here they begin to feed and grow, producing a new lesion light pink in color and of a dry, puffy nature. There seems to be no reason why sexual maturity could not be attained within the lung in this manner, and by this means the progeny of a single worm could infest an entire lung.

Modes of Infection.

The next question that suggests itself is, "How do these parasites gain ingress into the lungs?" Experimental proof is available to show that there are at least two methods. The rats already mentioned were given these larvae smeared on bread, in combination with which they were readily eaten. Most of these larvae subsequently passed out with the faeces, but apparently enough resisted the action of digestive ferments to find their way into the lungs, where they produced the characteristic lesions. Another experiment, conducted with three pigs to which these worms were fed in slop, gave very definite, positive results. These results are given in the appendix.

An additional mode of infection could be by inhaling the larvae as dust. For example, when the sweepings of a hog house, in which affected hogs were kept, were shaken up in a jar of water and allowed to stand over night, numerous, active larvae were found in the sediment, similar in all respects to those under discussion. The experiments on dessication further strengthen this theory, for, some of the larvae could be revived in fifteen minutes after they had undergone drying for a period of six days. The mucous of the nasal passages would be an excellent place for these dessicated parasites to lodge, and to continue their development.

Preventive Measures.

To effectively control these parasites prevention rather than cure must be the chief end in view. The common practice of continually raising hogs on the same piece of ground, can only result in a heavy infestation of the soil in all kinds of parasites. Changing the site of the hog lot every two or three years would certainly reduce this infection to a minimum. Experiments with the culture plots have shown that a heavy application of lime, is very effective in killing these parasites. In none of the plots which were subject to this treatment could living worms be found after two weeks. Other writers recommend a top dressing of kainit for the same purpose. Liberal application of these substances to pastures and yards, is the best method that can be recommended at this time.

As infection is especially likely in young pigs clean bedding and quarters should be provided for them. Dr. R. A. Craig has found adult lung-worms in three-weeks-old pigs, which fact together with the ascaris infection already mentioned, would indicate that young pigs may be parasitized directly by eating worms which have been excreted by older hogs. Segregation of affected individuals, and the careful examination of newly purchased stock, for symptoms as coughing, arching of the back, etc., are additional factors that can be recommended.

Appendix.

This experiment is a summary of the pig-feeding tests already referred to. This data could not be incorporated into the main body of the report as the pigs were being used for another purpose at the time this experiment was conducted. Altogether six pigs were used, and were selected to approximate the same size and development. These were divided into two groups of three each, which for convenience will be designated as Group A and Group B.

Group A.

These three pigs were used as checks. No worms were fed them, and they were simply kept in a clean concrete pen so that the chance of infection would be reduced to a minimum. Due to the fact that all of these pigs were some three months of age before they were segregated and had ranged in an open hog lot during this time, absolute freedom from infection could not be achieved. Examination of the lungs of these pigs, killed at the same time as Group B, gave the following results:

Pig	Right Lung	Left Lung	Male Worms	Female Worms
1	1 lesion	none	3	5
2	1 lesion	none	2	7
3	1 lesion	none	4	9

Group B.

The pigs of this group were fed lung-worm larvae at two different times, namely, on March 24 and May 12, 1921. The larvae were of different ages (from one to five weeks), and had been grown in culture plots in the laboratory. The feeding of these worms was effected by

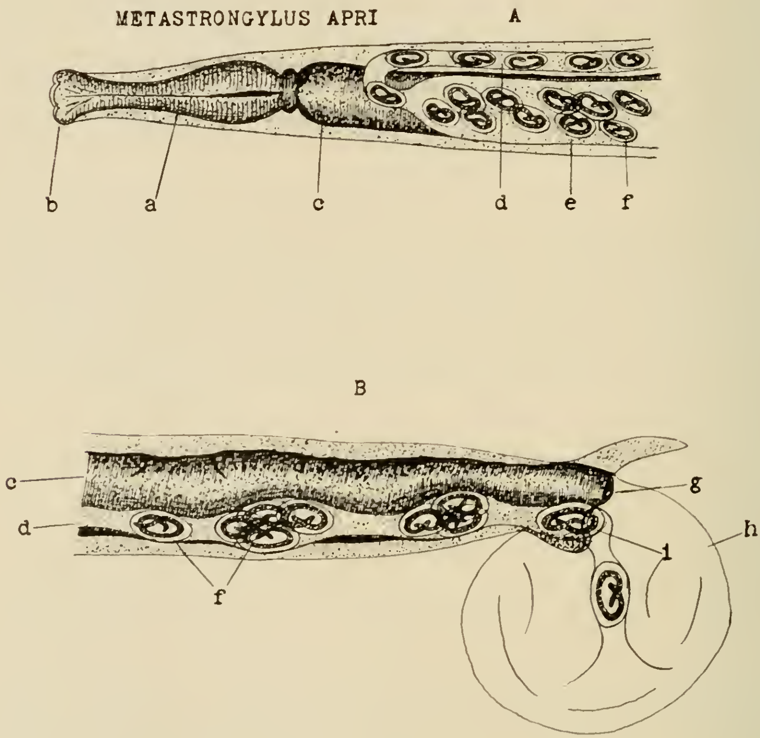
Pig	Right Lung	Left Lung	Male Worms	Female Worms
1	3 lesions	2 lesions	39	57
2	4 lesions	2 lesions	42	63
3	General verminiferous	bronchitis		

mixing them with grain in the form of a slop, and pouring this mixture into a trough. These pigs were killed on June first, of the same year, and the lungs, when examined were found to be badly infested. The following table shows the number of worms and lesions that were found.

The lungs of pig three were badly affected with these worms, although no localized lesions could be found. Partly developed worms were found in all of the bronchi of the lungs, which showed also a swollen, oedemic condition. The large number of males present in all of these lesions was a noticeable feature, and was doubtless due to some selective influence in the culture media.

Although these experiments are not as conclusive as could be desired, they undoubtedly prove that partly developed larvae will infect hogs under favorable conditions. *Purdue University.*

PLATE II.



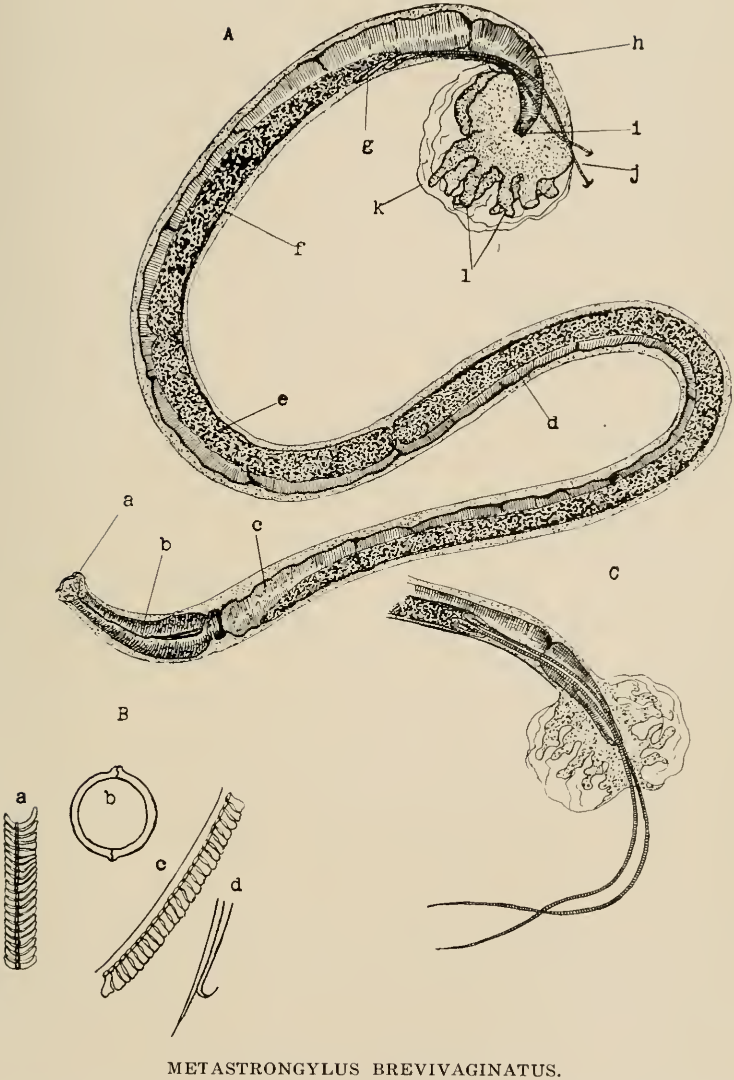
METASTRONGYLUS APRI.

A. Anterior view of female: a, esophagus; b, mouth with six lips; c, intestine; d, oviduct; e, uterus; f, eggs.

B. Posterior view of female: c, intestine; d, oviduct; f, eggs; g, anus; h, vulva; i, vagina.

PLATE III.

Metastrongylus Brevivaginatus.



METASTRONGYLUS BREVIVAGINATUS.

A. View of male: a, mouth with six lips; b, esophagus; c, intestine; d, e, testicles; f, seminal vesicle; g, anterior end of spicule; h, rectum; i, anus; j, spicules; k, bursa; l, costae.

B. Structure of spicule: a, top view; b, cross section; c, side view; d, end view.

C. M. apri, posterior view of male. Note comparative length of spicules.