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Parasites of Shrews in Brookings County, South Dakota

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PARASITES OF SHREWS IN

BROOKINGS COUNTY, SOUTH DAKOTA

BY

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BROOKINGS COUNTY, SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser — Date

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INTRODUCTION

The short-tailed shrew, Blarina brevicauda, and the masked shrew, Sorex cinereus, are the two representatives of the shrew family in Brookings County, South Dakota. These mammals, by the very fact that they are insectivores, are potential hosts for a varied fauna of parasites, as insects serve as intermediate hosts for a number of helminths. Although shrews are insectivores, they are omnivorous. An opportunist, the shrew will consume an abundance of any available food. They have been known to feed on a bird's nest (Horvath, 1965) and attack a garter snake (Byle, 1965). Hair from various small mammals was found in the digestive tract of short-tailed shrews examined by Lutz (1964).

Lutz (1964) described four fairly distinct strata in the short-tailed shrew's earthly habitat. The first stratum is the upper litter or surface. The second stratum is the soil-litter interface. It is at this level that the shrew does his primary foraging for snails, beetles, and other invertebrates. Below these two strata are the tunnel systems.

This is the first survey study of shrew parasites in the upper Midwest. In South Dakota, Fasbender (1956) described Hymenolepis anthocephalus, a cestode from B. brevicauda. The shrews collected for that study were from an area approximately one hundred miles south of Brookings. The species described was not recovered in the present study.

Two other survey studies conducted in different parts of the country include one by Oswald (1958), in which he described numerous

helminths from the short-tailed shrew in Ohio. The other survey study was conducted by Rausch (1962). In it he described a number of helminths taken from a shrew-mole, Neurotrichus gibbsii, in Oregon. Outside of the United States, survey studies have been conducted by Sharpe (1964) in England and by Lewis (1968) in Wales. The importance of the last studies lies not so much in the particular species of helminths discovered, but together with the two survey studies from the United States they help to point out the tremendous variability of parasitic fauna possible for shrews.

TRAPPING OF SHREWS

This study involved the parasitological examination of 124 shrews - 82 short-tailed shrews and 42 masked shrews. These insectivores were captured over a period of ten months, December 7, 1969, to September 14, 1970. Trap lines set in December were placed in a shelter belt. The first type of trap used was the common snap trap. These were baited with various nuts and exotic mixtures of rolled oats, peanut butter and various meat greases. The traps were placed wherever there were signs of small mammals. During the winter such places would be small openings in the snow by trees and grass clumps or in the snow itself. Often there would be small trails worn in the snow, indicative of the small mammal population present. The traps were attached to a long piece of string which was tied to anything available to prevent their being dragged off by mammals not killed by the traps. Marking the location of the traps was a necessity, for the snow often completely covered the small traps making their whereabouts questionable. In the summer marking was just as important, as tall grass in the trapping areas often completely hid the traps.

The time of checking traps varied. In the winter, when the temperature was constantly below freezing, trap lines were checked around 10:00 A.M. Since the carcass of the shrews froze almost immediately, there was no worry that the body would decompose. As the weather became warmer, the traps were checked earlier in the morning. During the summer, the traps were completely checked and reset by 7:30 A.M. due to

the fact that dead shrews decompose very rapidly during the warm summer nights and mornings.

As spring approached it was noticed that progressively smaller numbers of animals were being caught. The traps were moved from shelter belt to shelter belt without obtaining better results. When a number of traps were left over after setting a trap line in a shelter belt one morning, the remaining traps were placed along a fence-line. The next morning check showed no captures in the shelter belt, but the fence-line yielded a number of shrews and a couple of mice. Fence-lines were trapped exclusively from this time to September when trapping was terminated.

Because of the approaching warm weather it was decided to utilize only Sherman live traps in order to capture live animals. This procedure greatly cut down the incidence of shrews decomposing. Also, it was easier to find small parasites in the shrew, if they were alive and moving in a freshly killed host. If an excess of shrews were captured, that is, more than could be examined in one day, they were sacrificed by using ether, then frozen until later.

No bait was used in the live traps; they were placed in the small runs found in and along fence-lines or facing small holes in the ground. Other animals caught were a salamander, a rat, numerous voles, mice and weasels, and several birds.

METHOD OF EXAMINATION

The examination process was standardized as follows: Live shrews were killed with ether, while frozen shrews were thawed at room temperature. The specimen was then pinned to a wax board in a dissecting pan. The skin was cut on the ventral side, from the anal orifice to the lower jaw, and pulled back exposing the muscle structures. Cutting the muscle and rib cage from the posterior end to the anterior end of the shrew exposed the internal organs. All internal organs were removed and placed in a dish containing physiological saline if the shrew had been sacrificed or tap water if it had been frozen. The body cavity was searched for any parasite that might be present. The shrew was then skinned and examined for subcutaneous nematodes. In the examination of the organs themselves, the stomach was looked at first. It was opened in a solution placed in a petri dish. After carefully probing, the stomach was shredded and the contents thoroughly mixed in the dish. The contents of the petri dish were very closely examined under a binocular dissecting microscope. Other organs examined in this manner were the small intestine, large intestine, esophagus and trachea.

Presses were made of the lung and liver after they had been closely observed externally and cut open randomly. Two glass plates were firmly pressed together with either the lung or liver between them. These preparations were examined under a dissecting microscope. If any suspicious material appeared, it was further checked under the higher power of a compound microscope.

All parasites recovered were placed either into physiological saline or water depending on whether they were alive or dead. After the examination of a particular organ was completed, the parasitic organisms recovered were placed in A.F.A. (alcohol-formalin-acetic acid) fixative.

All live nematodes were relaxed by heating them in solution over an alcohol burner until death occurred. Caution had to be used to prevent cooking the nemas. The small stender dish containing the nemas never became hot enough to cause discomfort if placed on the back of the hand. The relaxed nemas were then placed in A.F.A. for 24 hours. Fixation being completed, the nemas were transferred into a mixture of 2 ml of pure glycerine, 97 ml of 70 per cent alcohol and 1 ml of saturated copper sulfate in a small stender dish and placed in a dessicator with calcium chloride. All liquid except the glycerine eventually evaporated and the nemas could then be stored in vials or mounted on slides. Nematodes handled in this manner as described by Thorne (1961) have a minimum of shrinking and distortion.

Flatworms and acanthocephalans were handled differently from the nemas. The flukes died soon after removal from the shrew if they were not already dead. Occasionally, tapeworms were recovered alive, and various methods of relaxation were tried. Some worms were placed in the refrigerator for a short period of time, while others were warmed in a manner similar to the method used on the nematodes. Still others were left at room temperature in saline until death occurred. The flukes and thorny-headed worms were placed on glass slides and

compressed by a cover slip to prevent excess distortion during fixation and to flatten the specimens to expose more clearly the internal organs. The cestodes were handled similarly. Some of the tapeworms were longer than the glass slide used. To facilitate handling, these specimens were wrapped around the length of the glass slide. After being in A.F.A. for 24 hours, fixation was completed. The specimens were put into glass vials and stored in a 70 per cent solution of alcohol.

The staining technique followed for flatworms and acanthocephalans is one suggested by Meyer and Penner (1958). Helminths to be stained were removed from their storage vials and placed in a stender dish containing 70 per cent alcohol. A series of these dishes was used, each containing a different solution. From the 70 per cent solution of alcohol, specimens were transferred to a solution of 70 per cent alcohol containing Semichon's Acetic Carmine where staining took place. The staining process took from a few minutes with the small tapeworms to 24 hours with some of the flukes. Destaining was accomplished in a solution of one per cent hydrochloric acid in 70 per cent ethyl alcohol. The specimens were carefully watched so as not to let the destaining proceed too far. In this method, the stain is taken out of certain tissues and left in others, making cellular and tissue differentiation possible. After destaining, the specimens were dehydrated by running them through a series of alcohols, (70, 80, 90 and 100 per cent). Clearing was accomplished by putting the specimens into a solution of one-half alcohol and xylol and then transferring them to a pure

solution of xylol. At this point the specimens were mounted on a slide in Permount, then put aside to dry.

Mounting nematodes involved an entirely different technique and is described by Thorne (1961). The nematodes to be mounted were removed from their storage vial and placed in a stender dish to facilitate access to them. A drop of glycerine was placed on a clean slide. The amount would vary according to the size of nema being mounted and the size of the cover slip used. The size of the glycerine drop is important, and it is better to have too little than too much. Excess glycerine is difficult, at best, to remove from a slide at this stage. After the drop of glycerine was placed on the slide the nema selected for mounting was placed in a dish containing minute glass rods. These rods were placed in the glycerine drop on the slide and arranged to form a triangle. The nema was placed in the middle of the triangle and in the position desirable for mounting.

The coverslip was then warmed slightly over an alcohol flame to facilitate the spreading of the glycerine when the coverslip was placed on the glycerine drop. The coverslip now in place was attached to the slide at the four corners by a small drop of ringing compound (Zut). Approximately one half hour later, the excess glycerine (outside of the coverslip) was carefully removed. The slide was then ringed with Zut and left to dry, leaving a permanent glycerine slide.

All skins obtained from the shrews have been marked and stored in a freezer for future examinations of external parasites.

PARASITES OF SHREWS

NEMATODA

Nematodes constitute free-living as well as plant and animal parasitic species. Most free-living and plant parasitic nematodes are microscopic. Animal nematodes that live in the body fluids are usually microscopic. Generally, the larger nematodes are found in the gastro-intestinal tract. Parasitic nematodes can be relatively harmless or can be the cause of severe disease.

LITERATURE REVIEW OF NEMATODES

In Blarina brevicauda from Illinois, Ogren (1953) described Capillaria blarinae from the cornified squamous portion of the esophageal epithelium and gave the histopathology of the nematode. Oswald (1958) recovered C. blarinae from 14 out of 93 short-tailed shrews collected in Ohio.

In the genus Sorex different species of Capillaria seem to be prevalent. Reed (1949) described a new nema, C. rauschi, from the small intestine of S. cinereus in Wisconsin. He separated C. rauschi from C. splenacea found in the small intestine of S. araneus in Europe and from C. minutus in the stomach and small intestine of Suncus caerulus in China by the size of the eggs and by the lack of lateral caudal alae. C. rauschi can be differentiated from most species of Capillaria by the mammilated outer shell of the egg. Lewis (1968) recovered C. incrassata in the bladder and C. oesophagicola in the esophagus of S. araneus in Wales.

The genus Porrocaecum belongs to the heterocheilid ascaroids and usually has only one intermediate host. The shrew seems to break this cycle and becomes an accidental second intermediate host in that it ingests the first host containing the larval nema. The nema is released in the intestine where it migrates to various sites and encysts, waiting to be ingested by the final host.

Schwartz (1925) described two larval nematodes belonging to the genus Porrocaecum. P. encapsulatum was encysted just under the skin of B. brevicauda. A second species, P. americanum, was encysted under the skin of a mole, Scalopus aquaticus. Chandler and Melvin (1951) recovered several specimens of P. encapsulatum and P. americanum from B. brevicauda and from Parascalops breweri, a mole. The encysted nemas were located subcutaneously and in the mesenteries of their hosts. The wall of the small intestines of B. brevicauda harbored cysts of P. encapsulatum. Sharpe (1962), in a survey study, observed a larva of a Porrocaecum encysted subcutaneously in S. araneus. Three species of larval Porrocaecum were recovered by Oswald (1958) from B. brevicauda in Ohio, that is, P. encapsulatum from subctuaneous cysts, P. americanum from cysts in the mesenteries and stomach wall, and P. ensicaudatum from the intestine. Rausch (1962) identified a single specimen of Porrocaecum as P. depressum or P. angusticolle, the adults of which occur in owls and hawks in Oregon. Rausch's specimens were obtained from a cyst in Neuretrichus gibbsii, the shrew mole.

Parastrongyloides winchesi was first described by Morgan (1928) from the intestine of Talpa europaea, a mole. Shrews in the same area

were found to harbor the same nematode. Oswald (1958) found P. winchesi in the intestine of B. brevicauda from Ohio. In his study he found that the females fell into two groups, the determining factor being a difference in size and number of eggs present. Both types of females were present in the same host.

Longistriata depressa (Dujardin, 1845) Shul'ts, 1926, of shrews has a cuticular swelling on the female which has led to some controversy as to taxonomy. Dikmans (1946) named a new nematode, L. caudabullata, on the basis of a permanent vesicular swelling on the dorsal side of the terminal portion of the female nema. This structure was not described by Dujardin. Dikmans considered this such an important and prominent structure that if Dujardin did not mention its presence, it must not have been present. Baylis (1939) recovered L. depressa but gave no description of the specimen. Thomas (1953) acknowledged the fact that Dujardin did not mention the gubernaculum and genital cone in his description and that there was no mention of the posterior cuticular inflation on the female of L. depressa. However, Dikmans pointed out the similarity between the bursas of the two nemas and then separated the two species on the basis of the cuticular inflation of the female. Thomas called this an unusual step in using the female to separate two species. On the basis that the bursas are similar and that there is the possibility that the cuticular inflation collapsed on Dujardin's specimens, Thomas considered L. caudabullata a synonym of L. depressa. Oswald (1958) recovered a number of L. depressa from shrews, B. brevicauda, in Ohio.

NEMATODES COLLECTED DURING THIS STUDY

Dissection revealed twelve species of nematodes, seven of which were parasitic and five of which were free living soil specimens that were probably ingested by the shrew when feeding (Tables 1 and 2). B. brevicauda harbored five parasitic species of nematodes and two species of soil nematodes (Table 1). S. cinereus harbored two parasitic species of nematodes and four species of soil nematodes (Table 2). These round worms were recovered from various parts of the body. Cysts were found in the subcutaneous tissue, stomach, small intestine and large intestine. The mature worms were found in the esophagus, stomach and small intestine. Parasitic nematodes found in B. brevicauda were not recovered from S. cinereus, although both species were trapped in the same area. In fact S. cinereus was relatively free of nematode parasites. This difference in nematode infections seems surprising, since both are insectivores and occupy the same habitat. Perhaps there are physiological limiting factors involved.

Trichuridae

Capillaria blarinae Ogren, 1953

Capillaria blarinae was recovered from 20.7 per cent of 82 short-tailed shrews examined. S. cinereus did not have this nematode. C. blarinae invades the esophageal epithelium. In seven infections a sloughing off of tissue into the lumen of the esophagus occurred.

This worm was one of the longer paraistes found in the study. It is 8-17 mm long and tunnels in a zig zag manner lengthwise in the

esophagus. This nematode was easily identified for three reasons:

1. The organ parasitized
2. The characteristic position it takes in the tissue
3. The barrel shaped, double plugged, egg of the genus Capillaria, Fig. 5.

The exact manner in which the shrew obtains the infection is not known. However, some species of this genus use an earthworm as an intermediate host.

Ogren (1953) recovered this nematode from shrews he examined from Illinois. Oswald (1958) found fourteen out of ninety-three short-tailed shrews infected in Ohio.

Three male Capillaria of indeterminate species were recovered from the stomach of the masked shrew. This represents a 2.3 per cent infection rate. For species identification, two mounted specimens were sent to Maybelle Chitwood, United States Department of Agriculture, Agricultural Research Service, Veterinary Sciences Research Division, National Animal Parasite Laboratory, Beltsville, Maryland. She stated that it was not possible to identify the nemas to species because a female specimen was not available. The eggs and vulva protrusion are used to separate the possible species, C. rauschi, C. splenacea, and C. minutus. Since Reed (1949) recovered C. rauschi from the intestine of S. cinereus in Wisconsin, Chitwood states that the nemas sent to her are quite probably conspecific with C. rauschi. The method of infection as with most Capillaria is probably in ingestion of an earthworm which harbors infective larva.

Trichostrongylidae

Longistriata depressa (Dujardin, 1845) Shul'ts, 1926

Longistriata depressa was recovered from 21.9 per cent of 82 *B. brevicauda* examined. The masked shrew was not infected. This small nematode, 1.7-2.2 mm, is usually seen in a coil when mounted. When alive, it resembles a very fine hair waving in the small intestine. At times there was blood in the intestine when the infection was exceptionally heavy, no doubt caused by the worms feeding on the villi. The male is equipped with a bursa and the branches of the dorsal ray are undivided at their tips, Fig. 2. The female posterior end terminates in a spike. On the dorsal side there is a large vesicular swelling, extending to the spike, Fig. 1. These characteristics are very important in classifying this nematode. As was discussed in the literature review, Dikmans (1946) listed this nematode as a different species, *Longistriata caudabullata*. However, Thomas (1953) while examining specimens from *S. araneus* from the Inner Hebrides, decided that *L. caudabullata* is a synonym of *L. depressa*. Oswald (1958) found this nema in twelve shrews. He stated that the parasite might have been overlooked in other shrews because of its small size.

The exact life cycle of this small nematode is not known. The usual method of infection for the family Trichostrongylidae is either by direct penetration of the skin or by ingestion.

Strongyloididae

Parastrongyloides winchesi Morgan, 1928

Parastrongyloides winchesi parasitized 1.2 per cent of 82 *B. brevicauda* examined. This worm was not found in *S. cinereus*. Only

one male, Fig. 4, and one female, Fig. 3, were recovered and these were from the same shrew. Since these nemas are so small, it is very possible that light infections would go unnoticed, the length of the female being 1.46 mm to 2.2 mm (Oswald, 1958). Morgan (1928) first discovered this nema in the intestine of a mole, Talpa europaea, in England. In Ohio, Oswald (1958) recovered it from seven shrews. He also has an interesting discussion on the nematode and states:

> "... the life cycle consists of an alternation between a free living generation which consists entirely of parthenogenetic females. The infection of the definitive host is accomplished by direct skin penetration by infective larva. Parastrongyloides winchesi differs from Strongyloides in that both males and females are present in the parasitic generation. Whether a free-living generation occurs and whether infection of the shrew is accomplished directly by skin penetration is not known."

Ascarididae
Porrocaecum americanum Schwartz, 1925 (larva)
Porrocaecum encapsulatum (Zeder, 1800) Schwartz, 1925 (larva)
Porrocaecum sp. (larva)

P. americanum occurred only once in 2.3 per cent of 42 S. cinereus examined. Five specimens of P. encapsulatum were recovered from four short-tailed shrews, constituting a 4.8 per cent rate of infection. Porracaecum sp. was recovered from three B. brevicauda for an infection rate of 3.7 per cent. Two of the shrews were only lightly parasitized while the third harbored cysts in the stomach, small intestine and large intestine, thirty-six in number. Although a good specimen was not obtained, the nematode was easily identified as Porrocaecum sp. and closely resembled Oswald's (1958) illustration of the third stage larva of P. ensicaudatum. However, P. ensicaudatum was found free in the

intestine by Oswald. The two other species of Porrocaecum were encysted subcutaneously and were visible only after the animal was skinned.

The above-named species of Porrocaecum have been recovered by Oswald (1958) in B. brevicauda. Schwartz (1925) and Chandler and Melvin (1951) recovered P. encapsulatum from B. brevicauda.

As stated previously, the adults of Porrocaecum usually occur as adults in birds, the shrew being an accidental intermediate host that became infected by ingesting an infected earthworm.

Soil Nematodes

Five species of soil nematode were found either in the intestine or the stomach of the shrew (Tables 1 and 2). Aphelenchoides sp. and Eudorylaimus sp. were in B. brevicauda. Chiloplacus sp., Plectus cirratus, Panagrolaimus sp. and Eudorylaimus sp. were in S. cinereus. Identification of these soil nematodes was either confirmed or completed by James D. Smolik from the Department of Plant Science, South Dakota State University. These nematodes were no doubt ingested by the shrews while feeding. These woil nemas are very common in this area, usually feeding on various fungi in the soil.

TREMATODA

The digenetic trematodes have one of the most complex developmental cycles of any parasite. Except for the schistosome blood fluke, these trematodes are monoecious. Fertilization may be accomplished by cross fertilization or self-fertilization. Since snails are the main

intermediate hosts for flukes, there are no doubt flukes of some species present in any area in which these mollusks are present. Flukes may parasitize many areas of the body, including blood, bile ducts, liver, pancreatic ducts, gastro-intestinal tract, lungs, trachea, and gall bladder.

LITERATURE REVIEW OF TREMATODES

A number of trematodes have been reported from shrews. Panopistus pricei was described by Sinitsin (1931) from the small intestine of the short-tailed shrew. In 1935, Krull established Zonitoides arboreus, a land snail, as an intermediate host of P. pricei. This particular mollusk is readily available to shrews, and it is not surprising that shrews are parasitized by this fluke. Oswald (1958) recovered the following trematodes in his study of helminths of the short-tailed shrew in Ohio: Entosiphonus thompsoni, Brachylaima rhomboideus and Panopistus pricei. In Sharpe's (1964) survey study one trematode, Brachylaimus sp., was recovered from Sorex araneus. Lewis (1968) recovered three species of flukes, Brachylaimus oesophagei from the esophogus, Dicrocoelium soricis from the gall bladder and bile ducts, and Opisthoglyphe exasperatum from the small intestine. All specimens were from S. araneus. In the northwestern United States the trematode, Xiphidiotrema lockerae, was described by Senger (1953) from the small intestine of S. bendirii, S. palustrus and S. obscurus permiliensis. Macey and Moore (1958) redescribed Opisthioglyphe locellus (Kossach, 1910) and worked on its life cycle. It was found that S. vagrans from Montana and an unnamed species

of shrew from Alaska near the Artic Circle harbored this species of trematode. The shrew-mole from Oregon has been found to be parasitized by Microphassus aspalacis (Rausch, 1962).

The water shrew, Neomys fodiens, is host to Opisthioglyphe (Neoglyphe) oschmarini in the European part of the U.S.S.R. (Shaldybin, 1966). Also, the trematode Opisthioglyphe (Neoglyphe) sebolevi from the U.S.S.R. parasitizes S. araneus and S. minutus (Shaldybin, 1966). Seesee (1970), stationed at the Artic Health Research Center in College, Alaska, collected shrews of the genus Sorex, specifically S. cinereus and S. obscurus and found that these shrews had an overall infection rate of 38 per cent for Neoglyphe soricis.

TREMATODES COLLECTED DURING THIS STUDY

Brachylaimatidae

Panopistus pricei Sinitsin, 1931

Panopistus pricei, Fig. 6, was found only in the short-tailed shrew. Though 20.7 per cent of 82 shrews were infected, the infections were usually light, there being from one to nine flukes in the large intestine. In only one shrew was the infection considered heavy. Fifty flukes were removed from the large intestine of a shrew caught 12 June 1970.

This fluke was first described by Sinitsin (1931) from the small intestine of B. brevicauda. Krull (1935) collected this trematode from the short-tailed shrew in Maryland, and Oswald (1958) recovered it from the short-tailed shrew in Ohio. Krull (1935) did a study on the life

cycle of P. pricei and stated that the snail Zonitoides arboreus is the intermediate host. The shrew no doubt obtains the infection by eating the snail.

Plagiorchiidae
Plagiorchis muris

Plagiorchis muris, Fig. 7 and 8, was recovered from 4.8 per cent of 82 B. brevicauda examined. Only one fluke was present in each of three of the hosts and forty-two were present in a fourth host. Although there apparently is no previous report of B. brevicauda as a host for P. muris, it is not surprising that this shrew serves as a host. P. muris is cosmopolitan, as indicated by Yamaguti (1958), and one should not be surprised in recovering it from any mammal or bird.

P. muris infects the shrew when the intermediate molluscan host, Lymnaea pervia, harboring the xiphidiocercaria is ingested. One interesting fact is that this mollusk is aquatic, and the four shrews which harbored this fluke were trapped on fence lines where there was no water. Water, if present in the area, was at a great enough distance to be discounted as being in the home range of the shrews caught. Therefore, the possibility arises of an undiscovered intermediate host, or the home range of B. brevicauda is greater than previously known. An estimate of the home range for B. brevicauda was calculated by Lutz (1964). He estimated the home range for males to be 0.03 to 2.26 acres and for females 0.01 to 1.54 acres.

Metacercaria (unidentified)

A masked shrew trapped on 9 December 1970 contained numerous matacercariae, 68 of which were collected. This represented a 2.3 per cent infection rate. The immature flukes were recovered from the stomach, the small intestine and the large intestine. Parts of a snail shell were found in the small and large intestine. The infection possibly resulted from the ingestion of the snail which harbored the intermediate stage of the fluke.

CESTODA

The mature or adult tapeworm is parasitic in the alimentary tract and in adjoining ducts of its host. These remarkable organisms vary in adult size from .45 mm in length, as in the Hymenolepididae, to over 30 feet in length, as in the Dibothriocephalidae.

LITERATURE REVIEW OF CESTODES

Rausch and Kuns (1950) state that "cestodes in North American shrews are strictly North American species, with none of the Eurasian forms represented insofar as the genus Hymenolepis is concerned." Neiland (1953) concurs with Rausch and Kuns and goes so far as to include a key for the identification of the hymenolepidid fauna of North American shrews in his paper. Voge and Rausch (1955) mention that the cestode fauna of shrews, with little exception, is limited to Hymenolepididae. They further state that the exceptions are the dilepidid, Liga soricis, the linstowiid, Oochoristica pennsylvanica, and Choanotaenia sp. found in some Alaskan shrews.

Numerous specimens of tapeworms belonging to the Hymenolepididae were recovered by Oswald (1958). Six species are named as follows: Hymenolepis sp., H. anthocephalus, H. blarinae, Pseudodiorchis reynoldsi, Protogynella sp., and Oochoristica pennsylvanica. Sharpe (1964), while conducting a small mammal study at the University of Bristol, did a parasitological examination of an undisclosed number of Sorex araneus. The recovered cestodes, five species, were Choanotaenia crassiscolex, H. singularis, H. scalaris, H. spinulosa, and H. scutigera. Lewis (1968) at the University of Wales, recovered Choanotaenia crassiscolex, H. scutigera, H. scalaris, H. singularis, and Protogynella blarinae from S. araneus and S. minutus.

Rausch (1962) examined ten shrews, Neurotrichus gibbsii, from Oregon and identified five specimens found in one of the shrews as Hymenolepis neurotrichi.

Voge (1953) described a minute cestode, Hymenolepis parvissima, recovered from Sorex bendirei bendirei. This is the smallest known cestode. The strobila length is 0.467 mm - 0.857 mm (average, 0.644 mm) and its greatest width is 0.153 mm - 0.204 mm. The proglottids number from 7 to 10. Previously the smallest known cestode was Protogynella blarinae, 0.750 mm long and 0.140 mm wide. Rausch and Kuns (1950) did a study on the cestodes of North American shrews. From B. brevicauda, the following cestodes were obtained: Protogynella blarinae, Diorchis reynoldsi, H. anthocephalus, and H. blarinae. S. cinereus harbored H. schilleri and H. falculata. S. c. cinereus, S. c. streatori, S. vagrans monticola, S. obscurus obscurus and S. o. alascensis, all

harbored H. parva. The hosts were collected from various parts of the central states, Alaska, and the western province of Canada. Locker and Rausch (1952) described four new species of Hymenolepis, plus other cestodes from Oregon shrews. They state:

> "The description of the four species of cestodes here brings the total number of species recorded from North American shrews to eleven. All the North American species are well characterized and can be readily differentiated. It would appear that the species of Hymenolepis parasitic in North American shrews have evolved quite separately from those found in the Eurasian mammals since no Eurasian species has so far been recorded from North America. When more nearly complete information has been obtained there may be derived from it some understanding of the zoogeographically important implications which are involved."

The four new species of Hymenolepis were H. macyi, H. kenki, H. sphenomorphus, and H. intricatus, all from S. v. vagrans trapped in Oregon. Oswald (1955) discussed the genus Protogynella and described a new species Protogynella pauciova from B. brevicauda and redescribed P. blarinae.

Voge (1955a) after examining shrews from California reported four species of hymenolepidid cestodes. They were H. sphenomorphus from S. vagrans; H. macyi from S. trowbridgei; H. kenki from S. pacificus; and H. falculata from S. palustris, S. vagrans and S. ornatus. In this paper a correction in the description of H. macyi was made in that an unarmed rostellum was mentioned. Also the terminal proglottids of H. sphenomorphus were described, this having been deleted in a previous paper. Voge (1955b) described a new cestode, H. virilis, from S. trowbridgei in California.

During a study on the helminths of the shrews in Montana, Senger (1955) noticed some differences or inaccuracies in some previous descriptions of hymenolepid cestodes. In his paper he tried to clarify certain points. The specimens he worked with were H. parva, Rausch and Kuns, 1950; H. schilleri, Rausch and Kuns, 1950; H. intricatus, Locker and Rausch, 1952; H. longi, Oswald, 1951; H. pauciglottis, Neiland, 1953 and H. macyi, Locker and Rausch, 1952. Senger (1955) came to the conclusion that no single characteristic can be used to identify species of Hymenolepis in shrews of North America.

Oswald (1951) trapped two smoky shrews, S. fumeus, while making a routine collection of small mammals. Only one shrew was suitable for study and this one yielded three new species of cestodes. H. longi and H. serrula are the first specimens bearing eight hooks to be recovered from a shrew. The third recovered specimen, H. lineola, bears ten hooks. As stated by Oswald, "It has become evident during the past decade that North American shrews harbor an abundant and singular cestode fauna."

A new species of Oochoristica was recovered from two short-tailed shrews from Pennsylvania (Chandler and Melvin, 1951). Neiland (1953) did a general study on shrew cestodes of northwestern United States. He recovered eight species and formed a small key for the species of Hymenolepis in North American shrews and a key to the species of Liga. Strong emphasis has been placed on the size and arrangement of the rostellar hooks in this key. Three species of shrews were examined. S. bendirii palmeri was host for Protogynella blarinae, H. intricatus,

H. kenki, H. longi, H. macyi, H. sengeri and Liga soricis. S. obscurus permiliensis was host for H. kenki, and S. v. vagrans was host for H. pauciproglottis. All specimens were recovered from shrews trapped in Oregon.

The one paper from South Dakota which deals with a cestode from a shrew is that of Fasbender (1956). In it she gives an excellent description of H. anthocephalus recovered from B. brevicauda in the southeastern part of the state. Voge and Rausch (1955) conducted a distribution study on shrew cestodes. Their area study consisted mainly of California and Alaska with some mention of Oregon, Ohio, Michigan and Wisconsin.

CESTODES COLLECTED DURING THIS STUDY

Four species of tapeworm were removed from the two species of shrew (Table I and II). H. parva and H. parvissima were recovered from S. cinereus, and H. blarinae and Pseudodiorchis reynoldsi were from B. brevicauda. The parasites were generally in the small intestine, although occasionally a few were recovered from the large intestine and three larval tapes were removed from the pancreas. There was a remarkable size difference in these tapeworms, ranging from approximately .45 mm to approximately 90 mm in length. Tapeworms infected 67.3 per cent of the 124 shrews examined.

Hymenolepididae
Hymenolepis parvissima Voge, 1953

This small cestode, Fig. 19, is the smallest known tapeworm (Voge, 1953), with an average length of 0.664 mm. It was present only in

S. cinereus and infected 33.3 per cent of these small shrews. H. parvissima possesses a well developed restellum bearing ten hooks, Fig. 20 and 21. Its hooks number between 7 and 10, 8 being the most frequent number (Voge, 1953). The shrew, S. bendirei bendirei, was the first insectivore found to harbor this worm (Voge, 1953). Since its discovery by Voge it has been reported by only one other researcher. Senger (1955) found this tape in S. palustris in Montana.

Hymenolepis parva Rausch and Kuns, 1950

H. parva, Fig. 10, another small tapeworm, 3 to 5 mm in length, infected 38.1 per cent of 42 S. cinereus examined, and was not present in B. brevicauda. In one especially heavy infection of H. parva there were 109 specimens. The pancreas was observed to have three unusually white spots on it. Upon opening them, three larval tapes, Fig. 14, were removed. Because of their immature stage identification was not possible. However, this shrew was heavily parasitized by H. parva; perhaps by the sheer fact of numbers and crowding in the intestine, these three larvae went up the pancreatic ducts and became lodged in the pancreas where they were able to survive, but their development was inhibited.

Hymenolepis blarinae Rausch and Kuns, 1950

Hymenolepis blarinae, Fig. 22, the largest tapeworm recovered in this study, measured up to 90 mm in length. It was present in 2.3 per cent of 42 S. cinereus and 14.6 per cent of 82 B. brevicauda. This was the only cestode present in both species of shrews. At times the

parasitism of B. blarina was so heavy that it seemed that there would be difficulty in the passage of the intestinal contents. However, no ill effects could be found.

H. blarinae has been reported from B. brevicauda by Rausch and Kuns (1950) from Wisconsin and by Oswald (1958) from Ohio.

Pseudodiorchis reynoldsi (Jones, 1944) Skrjabin and Metevosian, 1948

Pseudodiorchis reynoldsi was the most prevalent tapeworm. It parasitized 43.9 per cent of the 82 short-tailed shrews, but was not present in the masked shrew. This worm is 20-32 mm in length. One unusual feature is the armature of the rostellum. It has approximately 250 hooks in several closely overlapping rows. They are very small, 4-5 microns, and difficult to observe.

Jones (1943) first recovered the cestode from B. brevicauda in Virginia and placed it in the genus Diorchis. In 1948 Skrjabin and Metevosian erected the genus Pseudodiorchis and made P. reynoldsi the type. This species was redescribed by Oswald (1957) from specimens collected in Ohio and again reported by Oswald (1958) during a helminth study of the short-tailed shrew in Ohio. Rausch and Kuns (1950) in their study of North American shrew cestodes from Wyoming, Alaska and the western provinces of Canada, stated, "We have never observed this cestode in Blarina, nor in any other shrew species. It appears to have a restricted distribution." Since South Dakota is next to Wyoming this cestode has a greater range than previously thought.

Cestodes parasitized 60.9 per cent of the B. brevicauda examined and 67.7 per cent of S. cinereus. These totals are slightly higher

than were given for the individual cestode. The reason for this is that a few shrews were very lightly infected and identification of the parasite, beyond stating that it was a cestode, was impossible.

ACANTHOCEPHALA

Acanthocephalans, commonly known as thorny-headed worms, are internal parasites of many animals, the adults existing in the alimentary tract of vertebrates. A prominent identifying characteristic is a proboscis that is usually heavily armed at the anterior end of the worm. This is an organ of attachment and often perforates the structure to which it is attached.

LITERATURE REVIEW OF ACANTHOCEPHALANS

There are three previous reports of acanthocephalans in shrews from North America. Van Cleave (1953) reported an unidentified species of Centrorhynchus from the intestine of Neosorex palustris, and Oswald (1958), during a survey of the helminth parasites of Blarina brevicauda, recovered an encysted cystacanth, Centrorhynchus conspectus, from the mesenteries. In New York, cystacanths of Prosthorhynchus formosus were reported in the mesenteries of a short-tailed shrew by Nickel and Oetinger (1968).

ACANTHOCEPHALANS COLLECTED DURING THIS STUDY

Gigantorhynchidae

Mediorhynchus grandis Van Cleave, 1916

This is the first report of Mediorhynchus grandis Van Cleave, 1916 from a short-tailed shrew and the second report from the state of

South Dakota. Hugghins and Dauman (1961) found three females of M. grandis in the small intestine of a wild turkey, Meleagris gallopavo merriami, in the Black Hills of South Dakota.

The proboscis armature, including hook root length, distinguishes Mediorhynchus grandis from all other species of the genus. The two acanthocephalans in this study were removed from two different organs. One was attached to the wall of the large intestine and one was attached to the mesenteries. Both were juveniles and barely past the cystacanth stage. Van Cleave (1947) gives the hook root length as 0.073 to 0.093 mm, and Moore (1962) gives measurements of 0.077 to 0.09 mm. Holloway (1964) gives a slightly smaller range for the size of the hook root length, 0.075 to 0.086 mm. The hook root length of the two specimens in this study are 0.088 to 0.091 mm. These measurements coincide with the measurements of Van Cleave (1947) and Moore (1962), though larger than those of Holloway (1964).

Since the natural avian hosts of M. grandis are meadow larks, crows and grackles (Van Cleave, 1947, and Moore, 1962), the shrew probably obtained the infection in the same manner as these birds, that is, from ingestion of the intermediate stage in a grasshopper or a cricket.

DIPTERA
Cuterebridae

LITERATURE REVIEW OF CUTEREBRIDS

Cuterebrids of the genus Cuterebra are commonly called botflies or warble flies. In the larval form, they parasitize mainly rodents

and lagomorphs. Until this study, cuterebrids have not been recovered from shrews. Several surveys have been conducted to establish the amount of infection by botflies in rodent populations. Blair (1941) in northern Michigan, Test and Test (1943) in Indiana, Siegmund (1964) in New Jersey and Jacobsen (1966) in Manitoba report cuterebra infections in rodent populations but, in no instance was there an infected shrew. Buckner (1966) examined S. cinereus, S. arcticus, as well as B. brevicauda and found no cuterebrid larva present. However, rodents in the same area were infected with the botfly larva.

DIPTERANS COLLECTED DURING THIS STUDY

Cuterebra sp.

Three fly larva were recovered from two shrews, B. brevicauda, trapped on 16 July 1970. One shrew harbored in its respiratory passage two cuterebrid larvae in the first instar stage, Fig. 24. One was attached to the tracheal epithelium and the other was attached to the bronchial epithelium. It seems plausible that the larvae gained entrance to the shrew via its nostrils. This theory is supported by Ignoffo (1961) and by Catts (1967). Most of the reported examinations, if not all of them, conducted for cuterebrid infections have been external. That is, they looked for the large dermal swelling caused by the cyst-like pocket produced by the larva. If the previous investigators had done internal examinations they might have discovered a higher rate of infection and perhaps infections in previously unreported species. This

is the first report of the cuterebrid from a shrew. This also is the first written report of a cuterebrid from a small mammal in South Dakota.

Muscoid larva

The second fly larva recovered was from the large intestine of B. brevicauda. All that can be said is that it was a first instar larva and that it was probably parasitic. Confirmation of these two larvae was by C. W. Sabrosky, Systematic Entomology Laboratory, U.S.D.A., Washington, D. C.

BACTERIA

Minea polymorpha
Flavobacterium sp.

Minea polymorpha and Flavobacterium sp. were found in cysts from the lungs of B. brevicauda, 6 per cent infection, and S. cinereus, 2.3 per cent infection. The small cysts, approximately .27 to .34 mm in diameter, were usually not present in great numbers, but the cysts' very presence would seem to cause structural damage to the lung. These two species of bacteria are found in the soil and because of the shrew's proximity to the ground, it would be easy for it to inhale bacteria present in the soil.

Identification was completed by the South Dakota Department of Health, Pierre, South Dakota.

SUMMARY AND CONCLUSIONS

This study involved the parasitological examination of two species of insectivores, the short-tailed shrew, Blarina brevicauda and the masked shrew, Sorex cinereus. Dissection revealed an almost separate and distinct fauna for each species of shrew.

Blarina brevicauda

NEMATODA

- Parastrongyloides winchesi
- Longistriata depressa
- Porrocaecum encapsulatum (larva)
- Porrocaecum sp. (larva)
- Capillaria blarinae
- Aphelenchoides sp. (soil nematode)
- Eudorylaimus sp. (soil nematode)

TREMATODA

- Panopistus pricei
- Plagiorchis muris

CESTODA

- Hymenolepis blarinae
- Pseudodiorchis reynoldsi

ACANTHOCEPHALA

- Mediorhynchus grandis

DIPTERA

Cuterebra sp. (first instar)

Muscoid larva

BACTERIA

Minea polymorpha

Flavobacterium sp.

Sorex cinereus

NEMATODA

Capillaria sp.

Porrocaecum americanum (larva)

Panagrolaimus sp. (soil nematode)

Eudorylaimus sp. (soil nematode)

Chiloplacus sp. (soil nematode)

Plectus cirratus (soil nematode)

TREMATODA

Metacercaria (unidentified)

CESTODA

Hymenolepis parva

H. parvissima

H. blarinae

BACTERIA

Minea polymorpha

Flavobacterium sp.

Except for the one instance of parasitism of both species of shrews by H. blarinae and the one instance of lung cysts, the parasitic fauna of the two shrews was different. Why this is true is only speculation, for the two species were trapped at the same sites. Perhaps there is some physiological mechanism which tends to prevent the parasitism of B. brevicauda with the parasitic fauna of S. cinereus and vice versa. The infection rate for the two species of shrews was 87.1 per cent. B. brevicauda was more heavily parasitized by the various species of parasites recovered than was S. cinereus.

There seemed to be no seasonal distribution of the helminth parasites. However, a more intense study conducted over a number of years might show a seasonal occurrence of parasites.

This was the first study of internal parasites of shrews in the North-Central region of the United States. Host records have been established for the shrew as well as for the state of South Dakota.

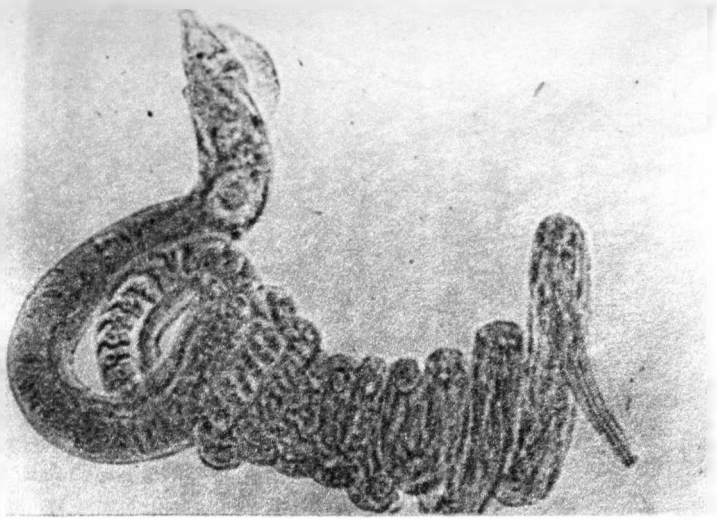

Figure 1. Female of Longistriata depressa

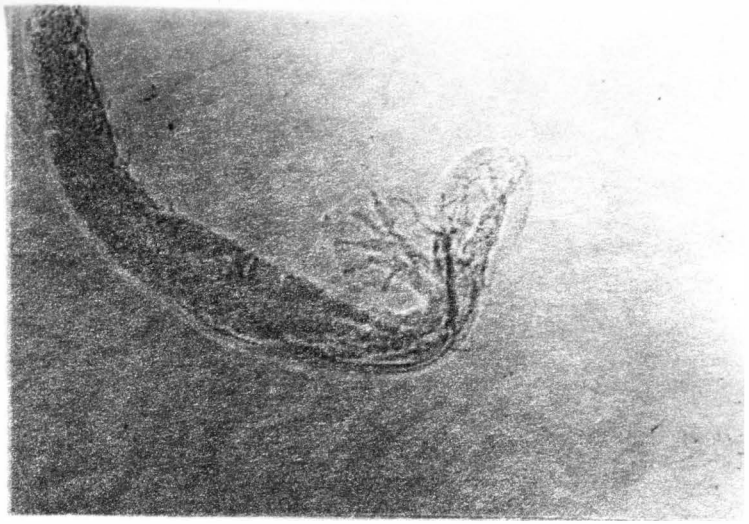

Figure 2. Bursa of Longistriata depressa

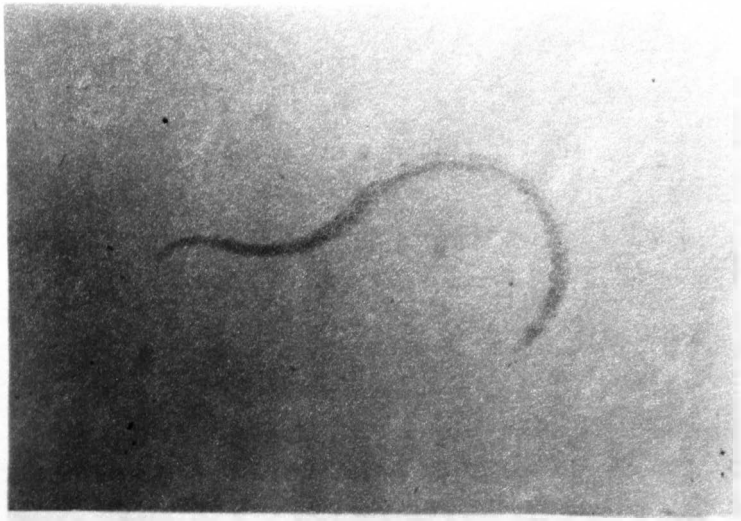

Figure 3. Female of Parastrongyloides winchesi

Figure 4. Male of Parastrongyloides winchesi

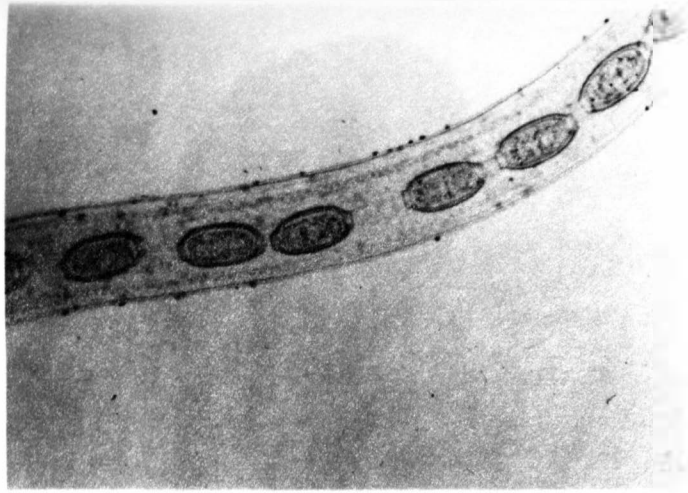

Figure 5. Eggs in Capillaria blarina

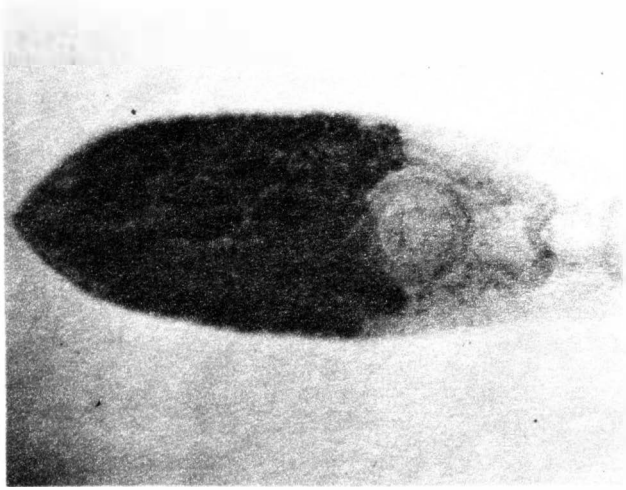

Figure 6. Panopistus pricei

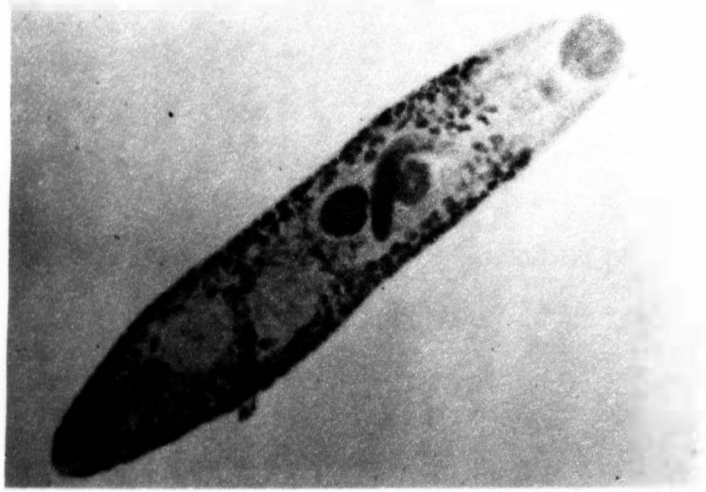

Figure 7. Plagiorchis muris

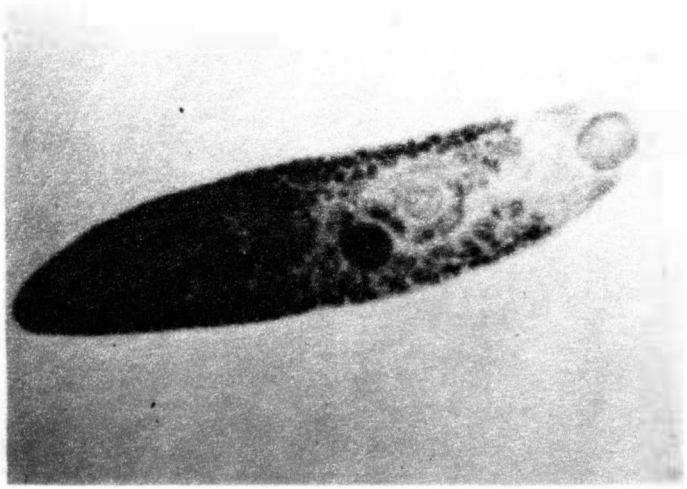

Figure 8. Plagiorchis muris

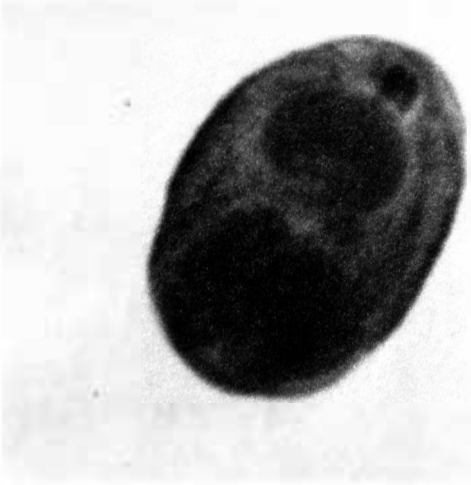

Figure 9. Metacercaria (unidentified)

Figure 10. Hymenolepis parva

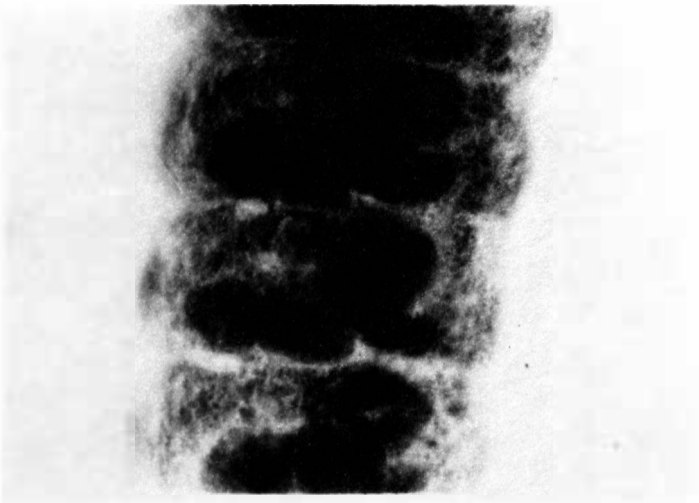

Figure 11. Testis of Hymenolepis parva

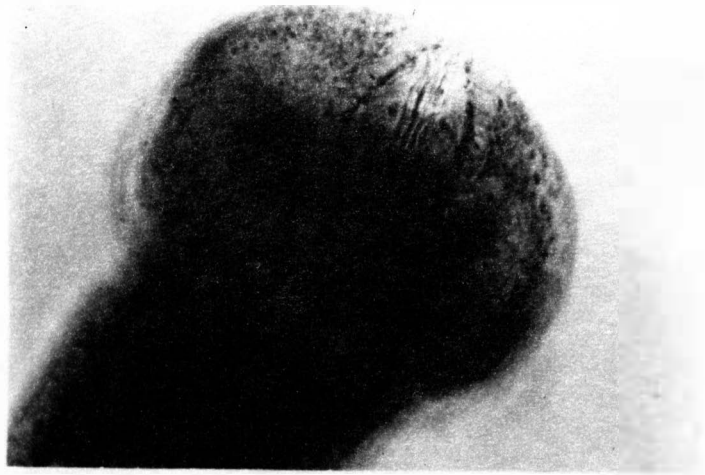

Figure 12. Scolex of Hymenolepis parva

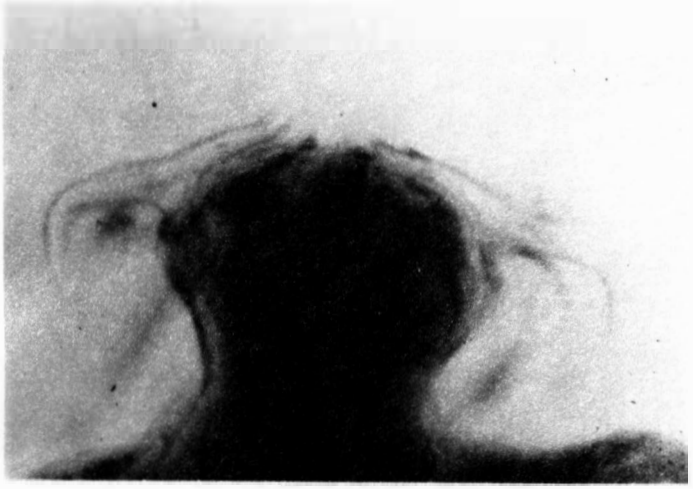

Figure 13. Rostellum of Hymenolepis parva

Figure 14. Tapeworm larva

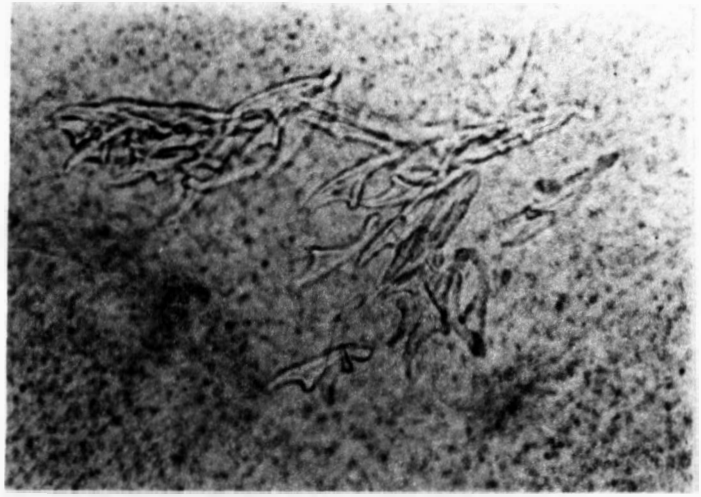

Figure 15. Hooks of Tapeworm larva

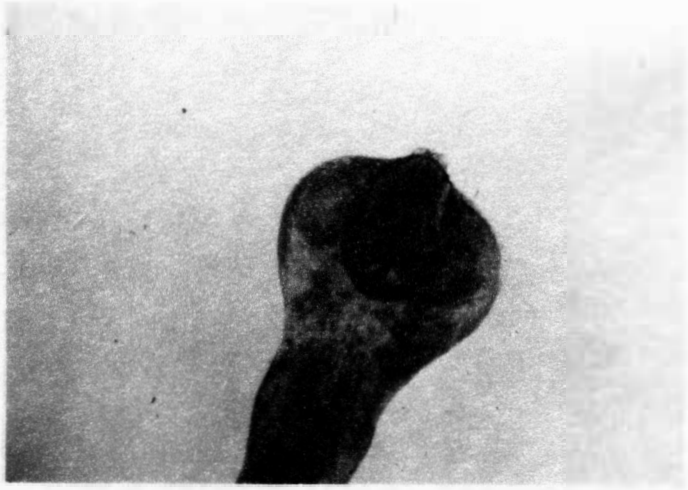

Figure 16. Scolex of Pseudodiorchis reynoldsi

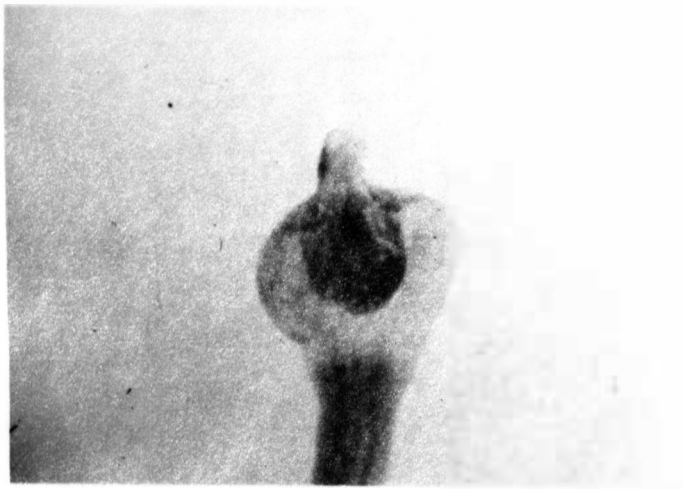

Figure 17. Scolex of Pseudodiorchis reynoldsi showing rostellum

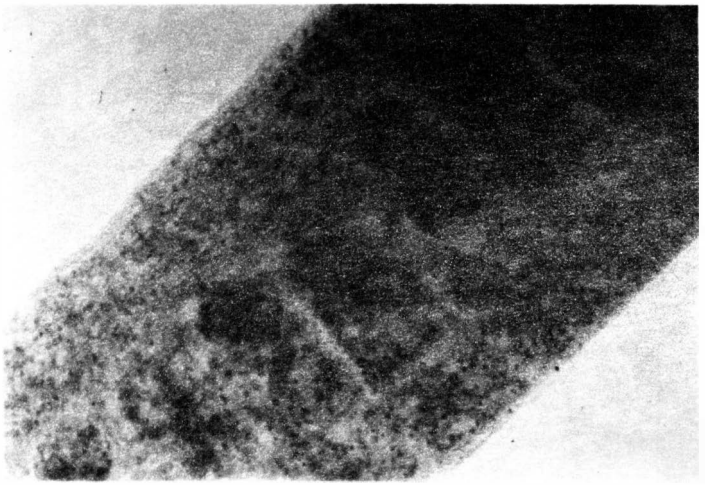

Figure 18. Testis of Pseudodiorchis reynoldsi

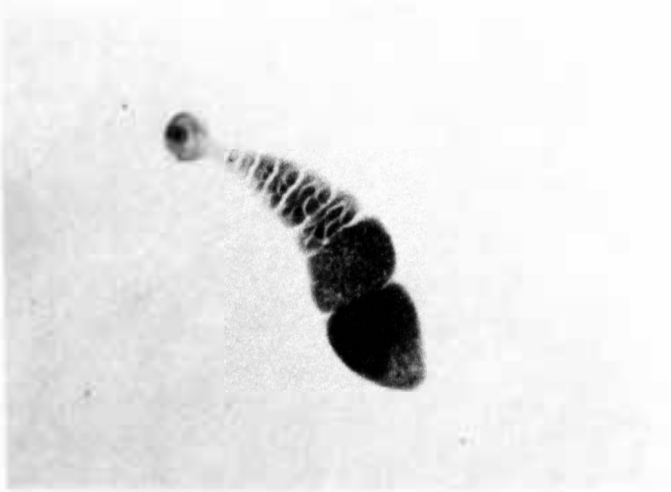

Figure 19. Hymenolepis parvissima

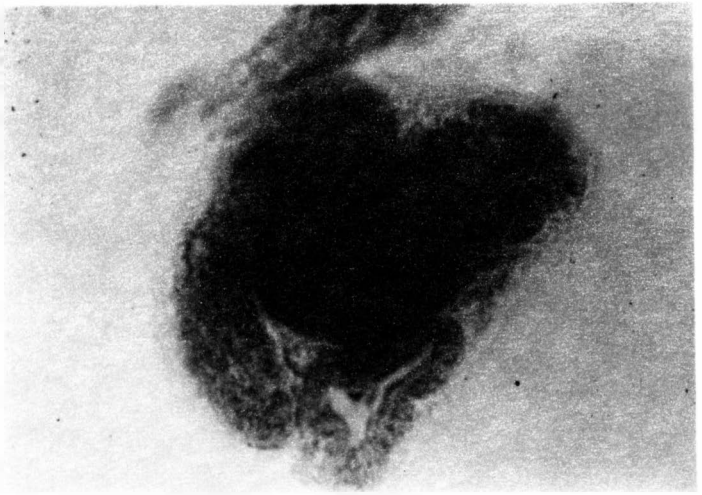

Figure 20. Face View of Hymenolepis parvissima

Figure 21. Hooks of Hymenolepis parvissima

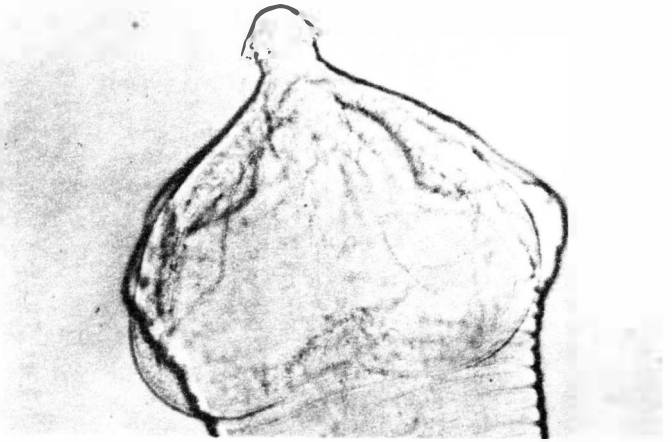

Figure 22. Scolex of Hymenolepis blarinae

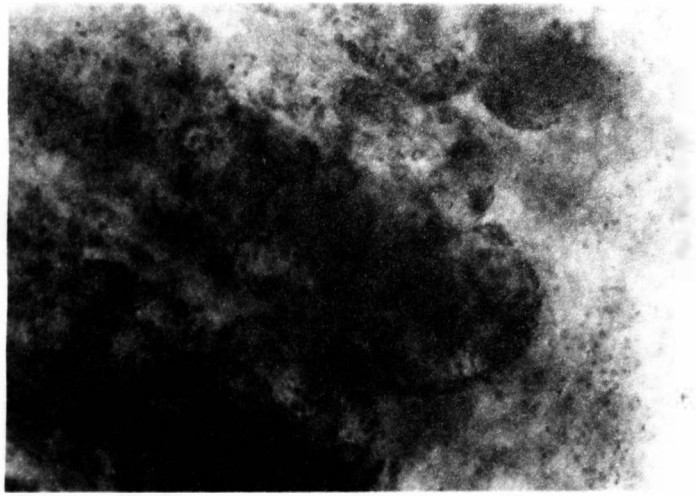

Figure 23. Testis of Hymenolepis blarinae

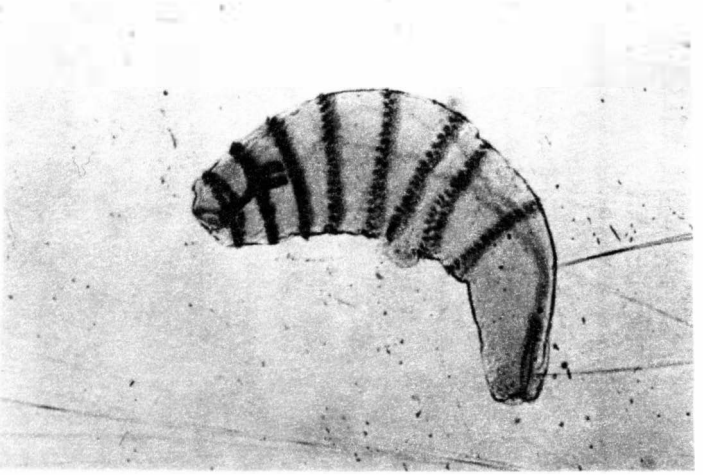

Figure 24. Cuterebrid larva

Table 1. Organisms recovered from 82 Blarina brevicauda.

Organism	Organ Infected	Per cent
NEMATODA		
Strongyloididae		
Parastrongyloides winchesi	large intestine	1.2
Trichostrongylidae		
Longistriata depressa	small intestine	21.9
Ascarididae		
Porrocaecum encapsulatum	subcutaneous cyst	4.8
Porrocaecum sp. (larva)	gastro-intestinal tract	3.7
Trichuridae		
Capillaria blarinae	esophagus	20.7
Soil Nematodes		
Aphelenchoides sp.	stomach	1.2
Eudorylaimus sp.	stomach	1.2
TREMATODA		
Brachylaimatidae		
Panopistus pricei	large intestine	20.7
Plagiorchiidae		
Plagiorchis muris	large intestine	4.8
CESTODA		
Hymenolepididae		
Hymenolepis blarinae	small intestine	2.3
Pseudodiorchis reynoldsi	small intestine	43.9
ACANTHOCEPHALA		
Gigantorhynchidae		
Mediorhynchus grandis	mesenteries and large intestine	1.2
DIPTERA		
Cuterebridae		
Cuterebra sp. (1st instar)	respiratory passage	1.2
Muscoid larva (1st instar)	large intestine	1.2
BACTERIA		
Minea polymorpha	lungs	6.0
Flavobacterium sp.	lungs	6.0

Table 2. Organisms recovered from 42 Sorex cinereus.

Organism	Organ Infected	Per cent
NEMATODA		
Trichuridae		
Capillaria sp.	stomach	2.3
Ascarididae		
Porrocaecum americanum (larva)	subcutaneous cyst	2.3
Soil Nematodes		
Panagrolaimus sp.	stomach	4.8
Eudorylaimus sp.	stomach	2.3
Chiloplacus sp.	stomach	2.3
Plectus cirratus	stomach	2.3
TREMATODA		
Metacercaria (unidentified)	gastro-intestinal tract	2.3
CESTODA		
Hymenolepididae		
Hymenolepis parva	small intestine	38.1
H. parvissima	small intestine	33.3
H. blarinae	small intestine	2.3
BACTERIA		
Minea polymorpha	lungs	2.3
Flavobacterium sp.	lungs	2.3

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