1990

Binder 208, Life histories E-G [Trematoda Taxon Notebooks]

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Life Cycles of Echinostomidae

The first complete life history of an echinostome to be recorded was that of *Echinostoma revolutum* by Johnson (1920). Subsequent life cycles, demonstrated experimentally, include that of *Hypoderæum conoideum* (Bloch) by Mathias (1925), of *Echinoparyphium recurvatum* (von Linstow) by Mathias (1927), of *Echinoparyphium aconiatum* Dietz by Riech (1927), of *Euparyphium murinum* Tubangui by Tubangui (1932), of *Euparyphium ilocanum* (Garrison) by Tubangui and Pasco (1933), of *Euparyphium malayanum* by Rao (1933), of *Echinoparyphium recurvatum* by Rašín (1933), of *Nephrostomum ramosum* by Azim (1934), of *Echinostoma coalitum* by Krull (1935), and of *Echinostoma revolutum* by Beaver (1937). The monograph of Beaver contains a review and analysis of the earlier papers. He noted certain discrepancies in the account of Johnson (1920) and suggested that the observations were made on material of more than one species. Indeed, the older descriptions are so incomplete and so inaccurate that it is exceedingly difficult to determine how many times one species has been redescribed or how many species have been confused. This condition is particularly prominent and perplexing when both adult and larval stages are considered together. Referring to descriptions of a

Echinochasmus bagulai Verma, 1935

orphological description of :

rcaria (Figs. 1 and 2.)

Echinostome cercariae described from marine snails are very few as compared ith those described from freshwater hosts, and chiefly relate to the works of Lebour 911), Martin (1955) and Cable (1956). There is no record of an echinostome ercaria from the snail *Natica marochiensis* and this is the first record of a marine ercaria from India.

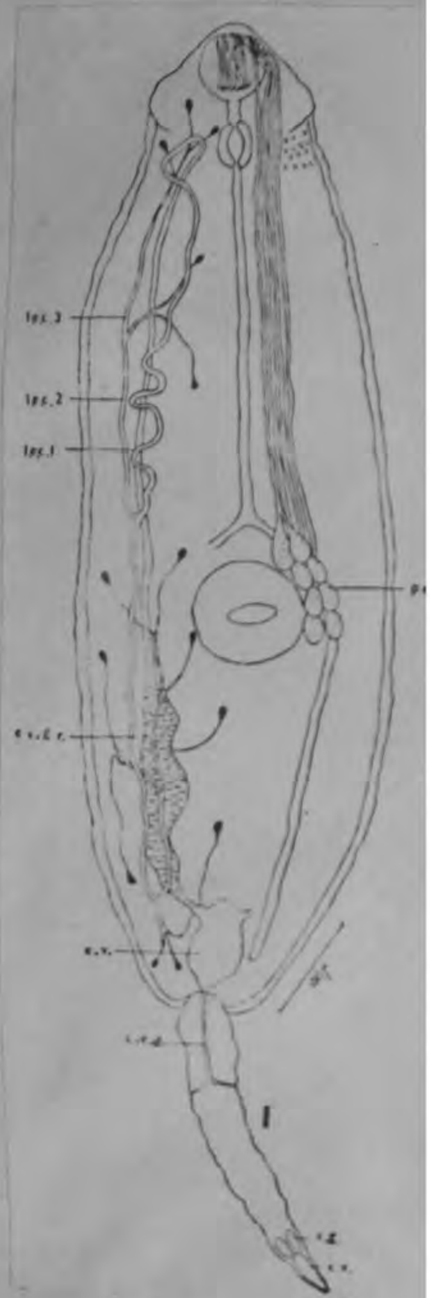
It was observed that cercariae emerged from *Natica* in greater numbers during day time than during nights. A single *Natica* kept under observation liberated during day time on three consecutive days 295, 193 and 147 cercariae and the numbers during the corresponding nights were 10, 7 and 4 thus exhibiting a diurnal periodicity. Diurnal periodicity was also observed by Cort (1922) and Rees (1948). The cercariae held in a finger bowl were found to accumulate on the side facing the source of light thus exhibiting photo-positive orientation and a similar observation was made by Rees (1948) in *C. purpurae*.

Live cercariae ranged from 0.91 mm. to 1.10 mm. in length and in contracted condition it ranged from 0.25 mm. to 0.28 mm. In moderately extended, fixed specimens length ranges from 0.58 mm. to 0.88 mm. and the width is from 0.16 mm. to 0.26 mm. Its shape is elongately oval. Tail is approximately equal to one-third the length of the body in normally extended specimens. At the posterior extremity of the tail is present a pair of glands which open into the vesicle. Acetabulum is situated in the posterior region of the middle third of the body and its diameter ranges from 82μ to 119μ. The future collar region is seen as a distinct thickening but is not well developed. The collar spines are seen as small refractile bodies when stained with vital stain methylene blue. Their arrangement (Fig. 2) is exactly similar to the type met with in the metacercaria (described below) and the adult. They are interrupted dorsally, with 12 spines on each half of the collar and the dorsal innermost overlaps the oral sucker. The inner row of spines measure 7μ in length and the outer row 9μ in length except the 8th and 10th spines on either corner of the collar which measure 11μ in length.

Four pairs of penetration glands are present on either side of the median line embracing the anterior border of the acetabulum and they open by four pairs of ducts at the anterior end. Unicellular glands are abundant throughout the body. Four pairs of glands are present along the posterior wall of the oral sucker and they open by fine ducts at the anterior end.

Oral sucker diameter is from 45μ to 62μ. Pre-pharynx is short and measure from 22μ to 49μ in length and 27μ to 38μ in width. Oesophagus is from 0.18 mm. to 0.27 mm. in length and it bifurcates in front of the acetabulum and the caeca extend to the posterior end of the body where they terminate blindly.

The excretory system.—The excretory vesicle is chambered and the posterior chamber is larger than the anterior. The vesicle opens to the outside posteriorly on the dorsal surface of the body at the point of attachment of the tail. From the anterior chamber at its antero-lateral border the two main collecting trunks arise. The trunks upto the posterior level of the acetabulum are broad and full of excretory granules. From about the middle of the acetabulum they are narrow and proceed forward to the level of the pharynx, taking approximately a parallel course all along. The two ducts (l.e.c.1) converge a little posterior to the pharynx. The main canals beyond this level are narrow. They make a triangular loop (characteristic of echinostome cercariae) and pass backward on to the inner side of the main ascending canal and bifurcate in front of the acetabulum into the anterior and posterior secondary collecting tubules (l.e.c.2). The anterior collecting tubule divides into two branches the tertiary tubules (l.e.c.3) whereas the posterior collecting tubule divides into three branches. The flame cell arrangement in this cercaria can be represented by the following formula $2\ [(3+2)+(3+3+3)] = 28$. A longitudinal canal starts from the posterior part of the vesicle and extends into the tail to one-fourth of its length and at that level it bifurcates into two lateral ducts which reach the sides of the tail.



Redia (Figs. 3 and 4.)

Heavily infected specimens of *Natica marochiensis* harbour rediae in all stages of development.

Well developed rediae measure from 0.90 mm. to 1.25 mm. in length and from 0.26 mm. to 0.29 mm. in breadth. The collar in younger specimens is conspicuous. It encircles the body in the region immediately posterior to the pharynx. Birth pore is dorsal and is on the left side just posterior to the collar, 0.15 mm. to 0.18 mm. from the anterior end. At about the middle are seen a pair of ventro-lateral appendages, the procruscula. In younger specimens they are quite pronounced long and vermiform. But in older specimens they appear as gentle curves.

Digestive system.—Mouth leads to a small vestibule just in front of the pharynx. A little posterior to the mouth opening and on either side is seen a small mass of gland cells which open into the vestibule. The pharynx is well developed and its diameter is 44μ to 56μ. The pharynx leads into a sacculate gut extending as far as the level of the appendages in younger specimens. In older forms having cercariae the sacculate gut is pushed to one side.

Cercariae in various stages of development occur in older rediae, numbering from four to eight and besides a few cercarial embryos also occur. They lie freely in the body cavity of the redia and move back and forth with the movement of the redia. The body of the fully developed cercaria near the birth pore region measures from 0.48 mm. to 0.52 mm. in length.

Metacercaria (Figs. 5 and 6.)

The earliest record of an echinostome metacercaria in a marine bivalve (*Scorbicularia tenuis*) is that of Villot (1879). Subsequently, various marine bivalves are described as harbouring echinostome cysts [Lebour (1908) and Stunkard (1938)]. This is the first record of echinostome cysts from *Katelysia opima* (and the first to be described from India though two other species of *Katelysia* (*Tapes*) *pullastra* and *K.* (*Tapes*) *decussatus* are known to harbour echinostome cysts [Lebour (1908) and Palombi (1934) respectively].

A maximum of 395 cysts were once recorded from a single infected bivalve. These cysts are found encysted in the foot usually at the junction of the posterior half of the body with the foot, though occasionally a few are found encysted in the gill-lamellae and the mantle.

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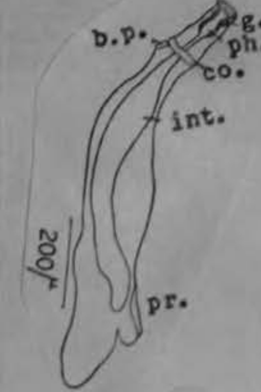

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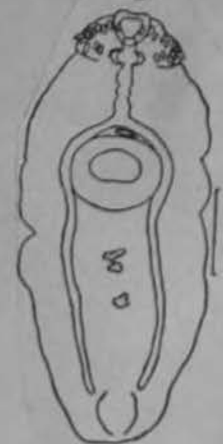

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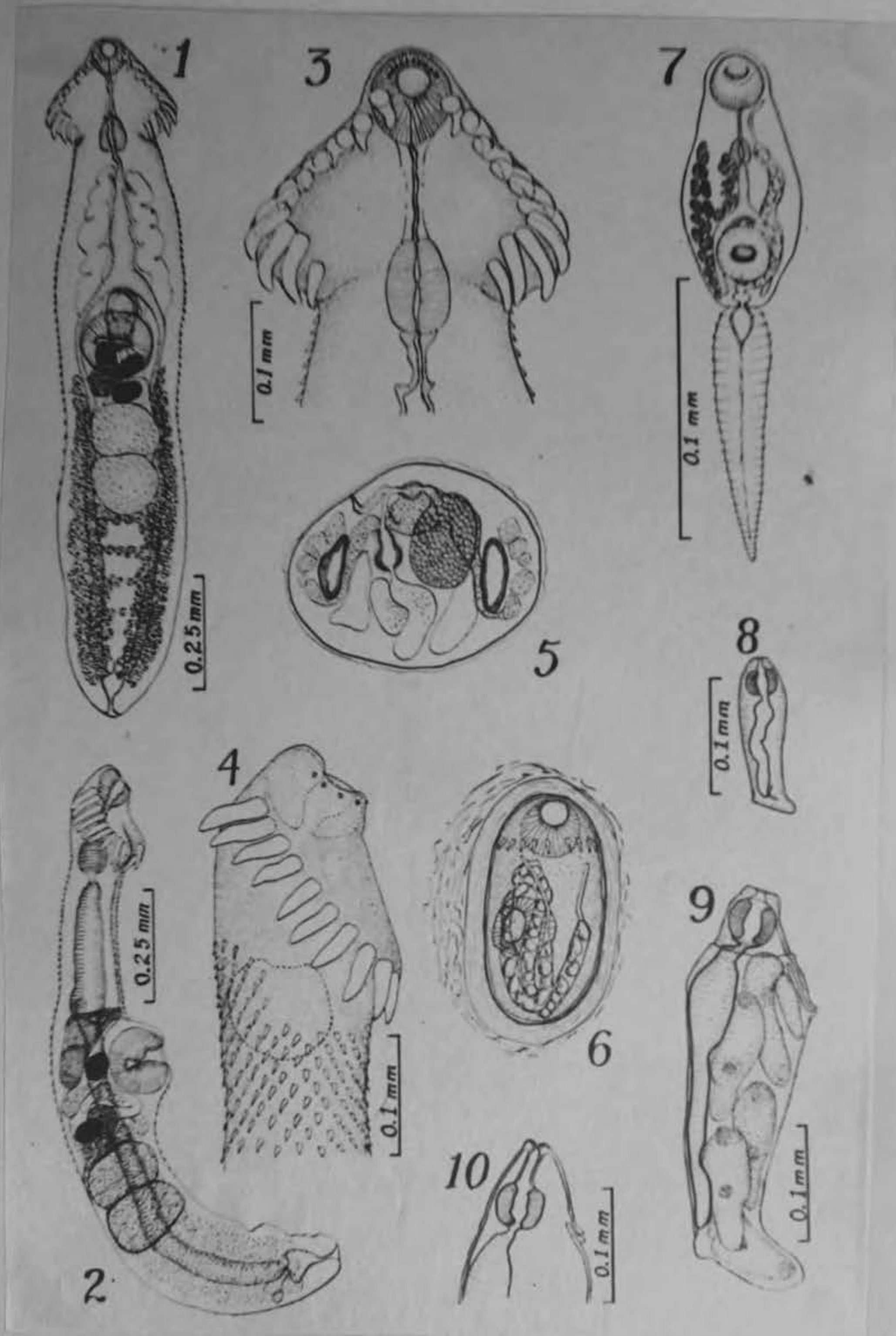
Echinochasmus donaldsoni Beaver, 1941



Adult in pied-billed grebe (Podilymbus podiceps) and experimentally in pigeons.

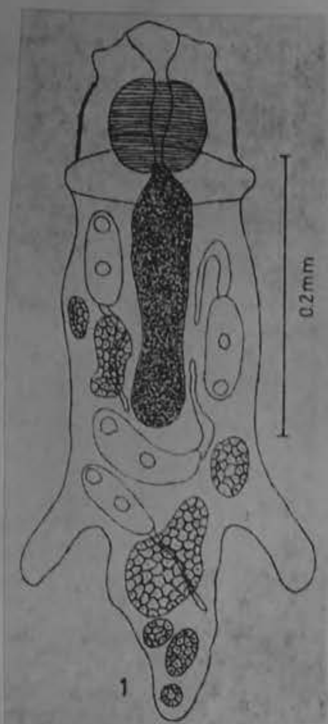
Snail hosts: Amnicola limosa, A. lustrica at Douglas Lake. Gymnocephalous cercariaedevelop in rediae, emerge and encyst in numerous species of small freshwater fishes and develop collar spines typical of echinostomes.

Reference: Jour. Parasit., 27:347-355. 1941

Echinochasmus zubedakhaname Nasir and Dìaz, 1968

Summary. The cercariae of *Echinochasmus zubedakhaname* n. sp. on emerging from the snail first intermediate host, *Pomacea glauca*, both in natural and experimental conditions, encyst in the intestinal mesenteries of the fish, *Lebistes reticulatus*. The cysts from these fish when fed to pigeons and chickens develop, in the small intestine, into adult echinostomes with the expulsion of echinostome eggs in feces after the seventh day of the experimental infection. The adults possess a crown of 20 collar spines interrupted dorsally in oral region while no such spines exist in the cercariae. The natural definitive host is an avian species, *Fluvicola pica*. The cercaria is devoid of a finfold on its tail and the contents of its cystogenous glands are rhabditiform.

FROM NASIR AND DIAZ, 1968



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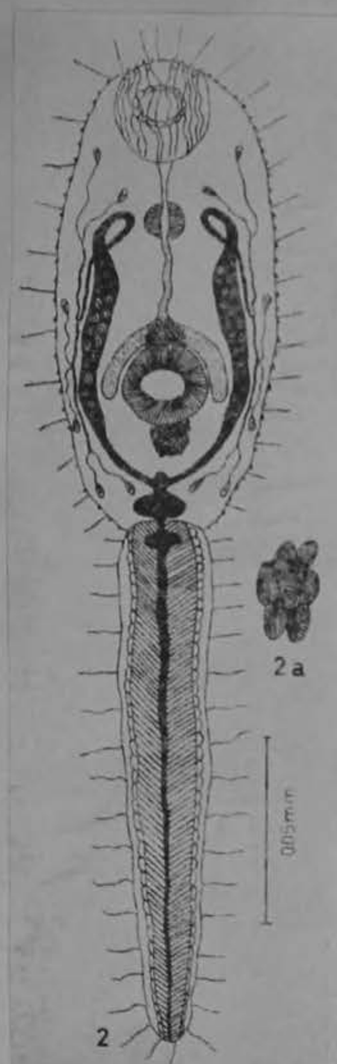

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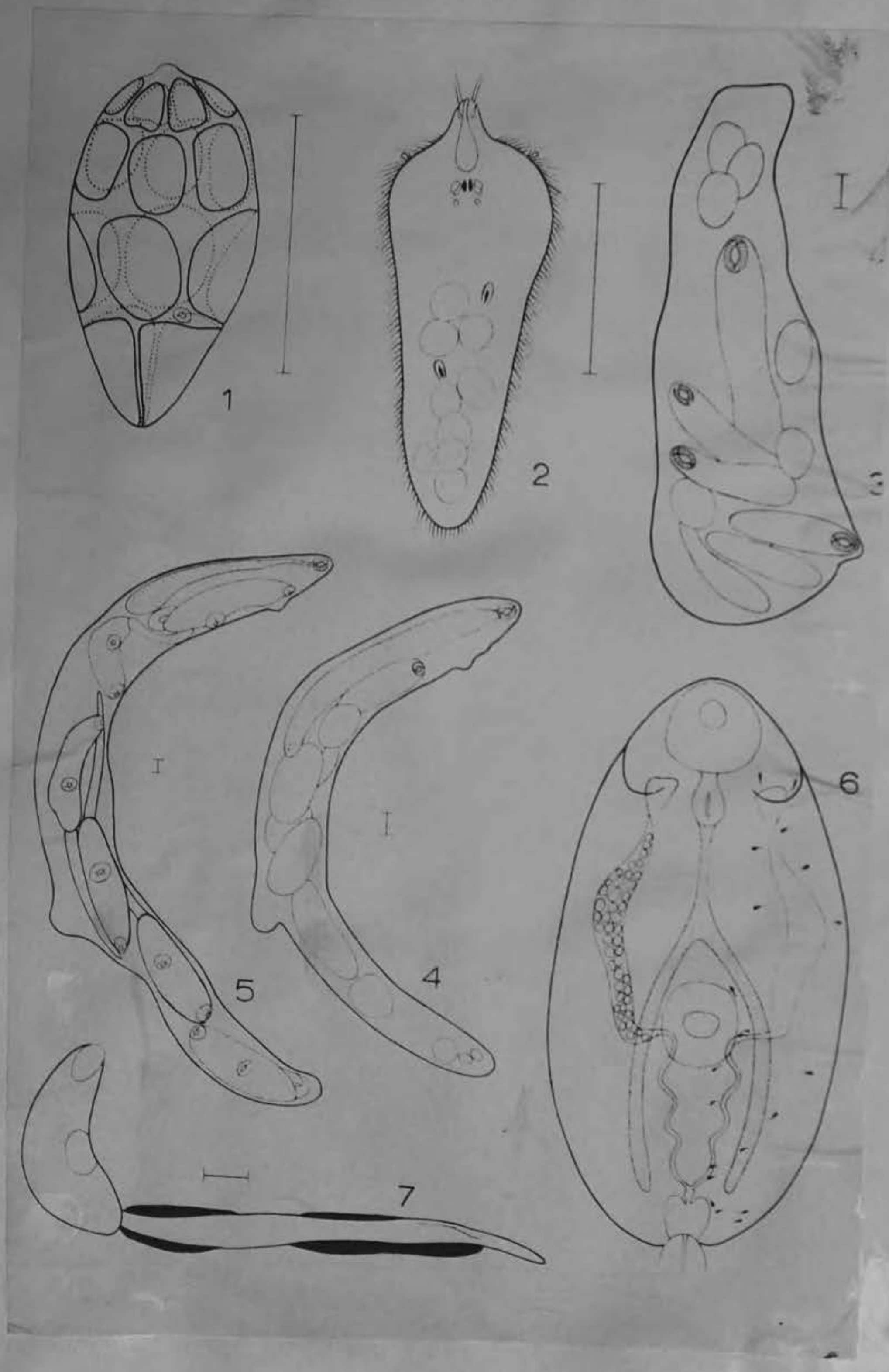
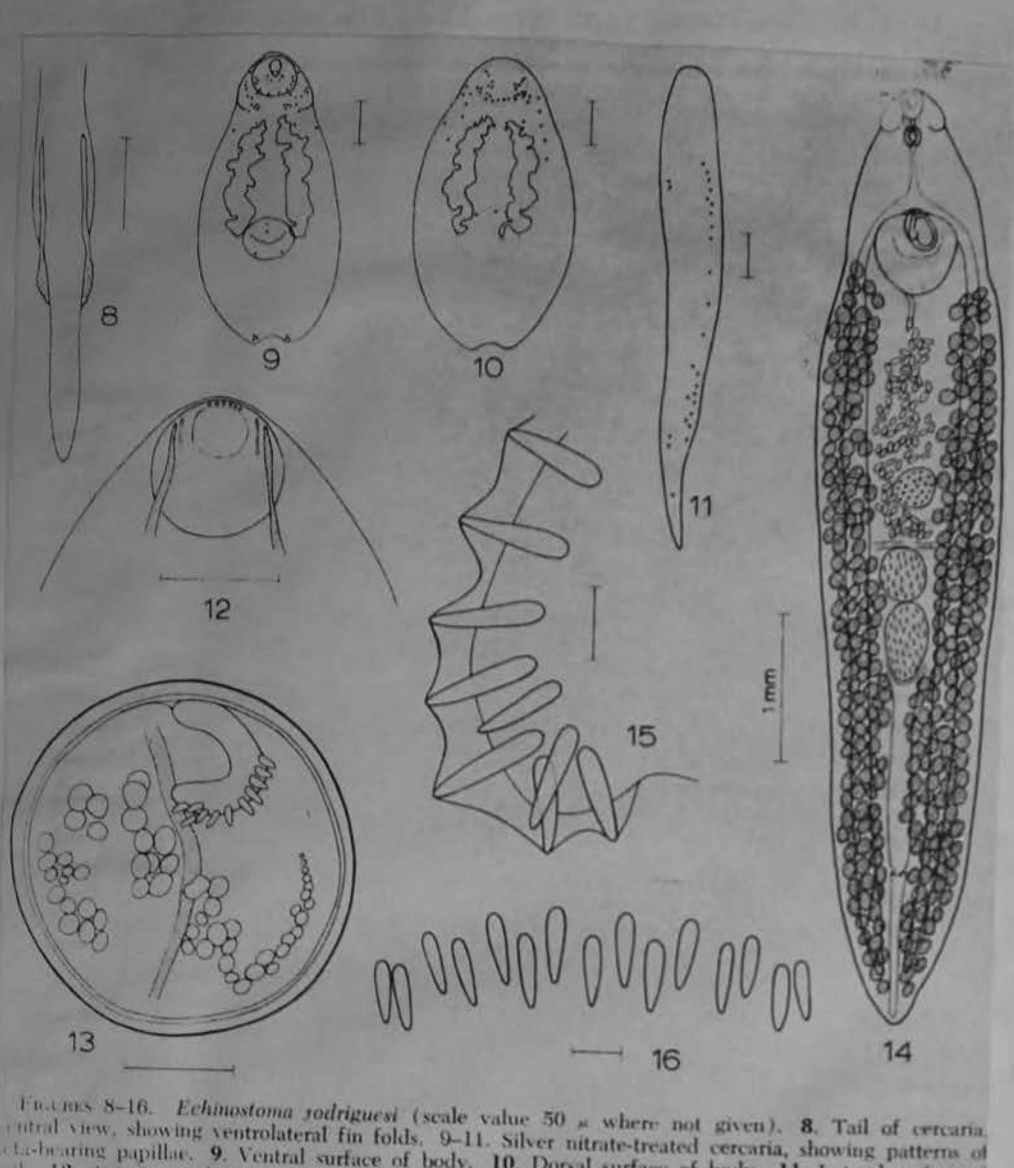
SEE REPRINT FOR DESCRIPTIONS OF LARVAL FORMS.

flame cell formula $2[(2)+(2+2)]=12$; caudal

Echinostoma rodriguesi Hsu, Lie, & Basch, 1968

A 37-spined echinostome from Brazil. One sporocyst generation and at least two redial generations in 1st intermediate host, Physa rivalis, The same physid snail, or the planorbid snail, Biomphalaria glabrata, served as second intermediate host in the lab. Adults experimentally in chicks, pigeons, hamsters, mice.
Ref.: J.P. 54(2):333-339. 1968.





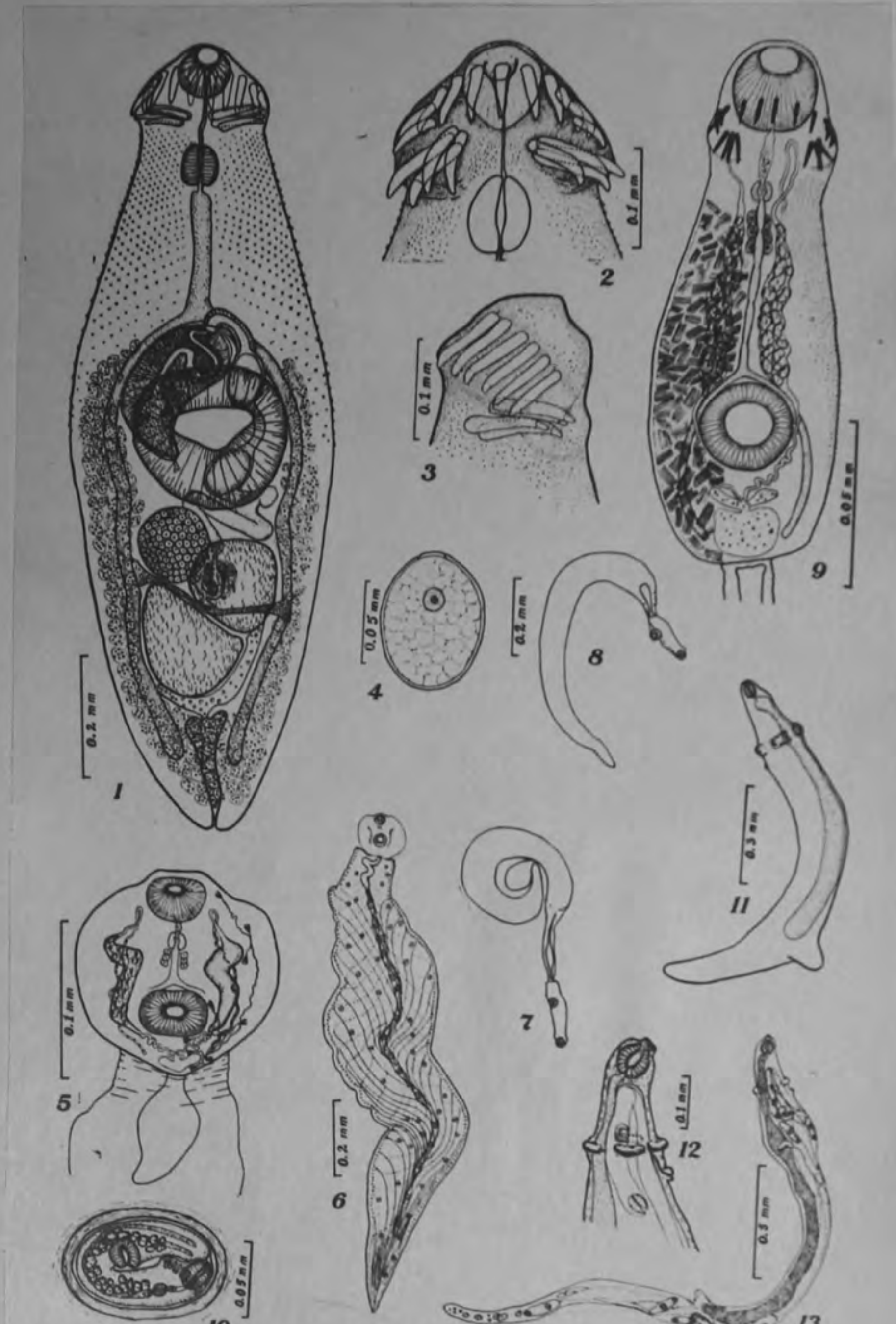
FIGURES 8–16. *Echinostoma jodriguesi* (scale value 50 μ where not given). **8**. Tail of cercaria, ventral view, showing ventrolateral fin folds. **9–11**. Silver nitrate-treated cercaria, showing patterns of seta-bearing papillae. **9**. Ventral surface of body. **10**. Dorsal surface of body. **11**. Lateral surface of tail. **12**. Anterior end of cercaria stained with Nile blue sulphate, showing pores of cephalic glands on dorsal lip of oral sucker and paraesophageal gland ducts on lateral lip. **13**. Metacercaria. **14–16**. Adult. **14**. Microprojector drawing, collar spines not shown. **15**. Corner and four lateral spines of collar. **16**. Dorsal spines of collar.

illiantly with all three stains; second group robably identical to paraesophageal gland ducts ... 1966b). Gland cells proper to both groups ... stained.

opaque layer 3 thick. In the laboratory, cercariae encyst in pericardial cavities of *Biomphalaria glabrata* and infected or uninfected

Echinostomidae

Petasiger nitidus Linton,1928



Petasiger nitidus

Adult in horned grebe,Colymbus auritus, and experimentally,canary
Cercariae (large-tailed echinostome) develop in rediae in
Helisoma antrosum percarinatum (Walker) , when eaten by
small fish, the body encysts in mucosa of lower pharynx.
Ten or more small fishes and minnows were infected.

Reference: Beaver,Paul C. 1939
Jour.Parasit.,25:269-276.

Petagaster chandleri ABdEL-Malek, 1952

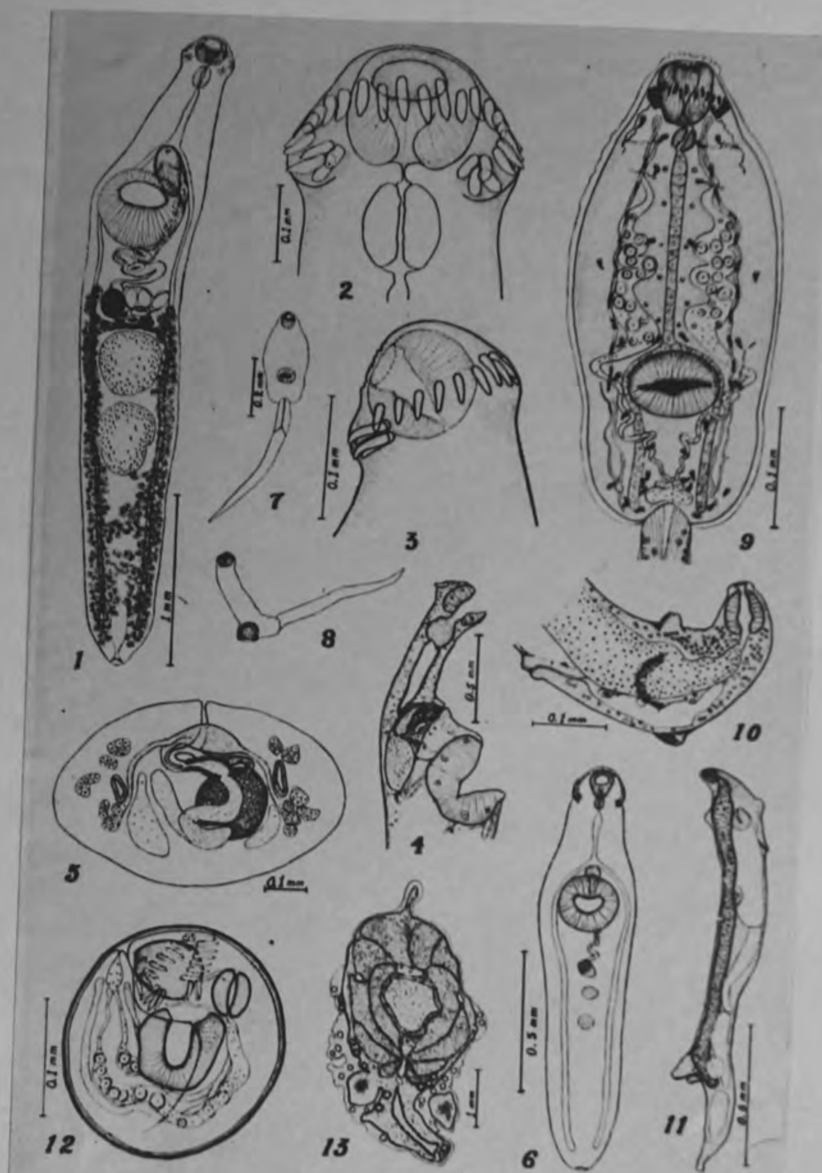
Final host: Podilymbus podiceps, pied-billed grebe
at Lake Itasca, Minnesota

Snail host: Helisoma corpulentum

2nd Intermediate hosts: various species of fishes especially
Perca flavescens and Ameiurud nebulosus
also tadpoles.

Reference: Abdel-Malek, Emile T. Jour.Parasit., 39 (2):152-157.
1953.

Euparyphium melis (Schrank,1788)



Euparyphium melis.

Adults in North American mink, Mustela vison, and in several species of European Mustelidae (Mustela foina, Lutra vulgaris, Meles taxus). Experimentally in ferret.

Echinostome cercaria with 27 collar spines develop in redia with long gut, prominent appendages, broken collar and no pigment, plain tail, in Stagnicola emarginata angulata at Douglas Lake. Metacercariae encysted in skin in region of cloaca of various tadpoles

Reference: Beaver, Paul C. 1941. Jour. Parasit., 27:35-44.

The life history of Psilostomum ondatrae was described by Beaver, 1939, Jour. Parasit., 25:383-393

Adult : field hosts: muskrat, Ondatra zibethica (Ontario)
California gull, Larus californicus (Oregon)
chicken, (Gallus gallus (Colorado)
osprey, Pandion haliaetus carolinensis (Penna)
Cooper's hawk, Accipter cooperi (Mich.)

Laboratory infections in pigeon, duck, chicken, canary

(it develops in pits in proventriculus and is pathogenic).

Eggs pass out in feces begin to hatch after 16 days in water.

Miracidia are fully ciliated and have epidermal plates in four rows: 6-6-4-2. With eye spots. 1/pr. flame cells.

Snail host: Helisoma antrosum percarinatum

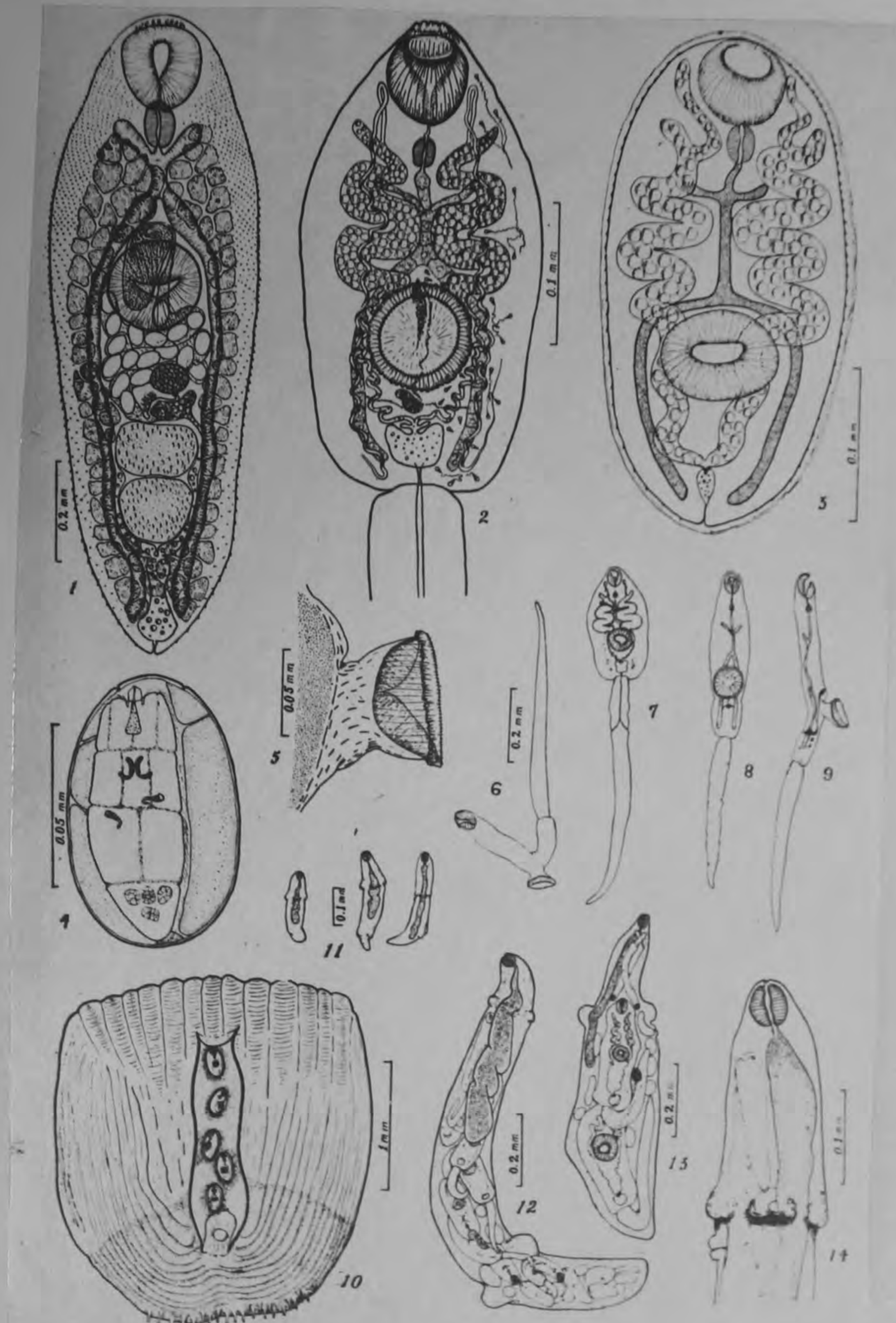
Mother rediae produce both second generation rediae and cercariae.

Cercariae leave snail during night and penetrate lateral line and nares (and to some extent scales) of freshwater fish (of several species especially perch, Perca flavescens; rock bass, Ambloplites rupestris; small mouth black bass, Micropterus dolomieu; pumpkin seed (Eupomotis gibbosus; and bluegill, Lepomis pallidus.

Cercariae are echinostome-like and identified as Cercaria thomasi McMullen, 1938

Entire life cycle i.e. the various stages are very echinostome-like and Beaver concludes a close relationship between Psilostomidae and Echinostomidae.

Life history of Psilostomum ondatrae from Beaver, 1939



Psilostomum reflexae (Cort, 1914)

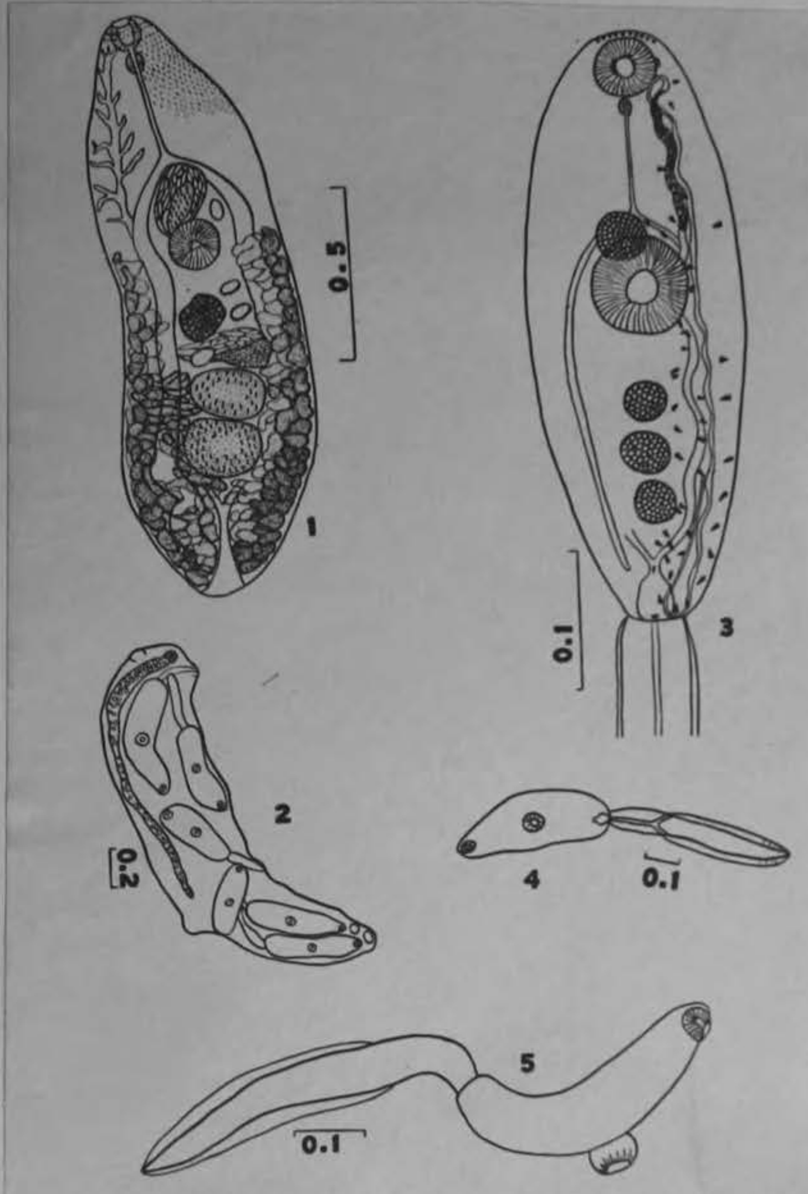


FIG. 1. Adult *Psilostomum reflexae* showing general morphology.
FIG. 2. Redia of *P. reflexae*.
FIG. 3. Cercaria of *P. reflexae* showing details of the excretory system.

Adult in small intestine of domestic chicken (Experimental host)
Cercariae develop in rediae in Stagnicola reflexae
Metacercariae in mantle cavity of Physa gyrina, Stagnicola reflexae, and Heliosoma sp., infective 5 to 7 days after encystment.
Attempts to infect ducks, sparrows, pigeons, rats, guinea pigs, mice, rabbits, cats were unsuccessful. The natural host is unknown.
Reference: Feldman, Seymour I. 1941. Jour. Parasit., 27:525-533.

LIFE CYCLE OF PSILOCHASMUS OXYURUS in ARGENTINA

Ref.: Szidat, L. 1957., Zeit.Parasit.,18(1):24-35.
Final host: ducks, etc. in many parts of the world
Snail host: <u>Littoridina australis</u>. Cercariae develop in rediae. Penetrate snails od the same species and encyst.

The genus <u>Psilochasmus</u> is considered an aberrant genus of Echinostomidae and not a member of the Psilostomidae

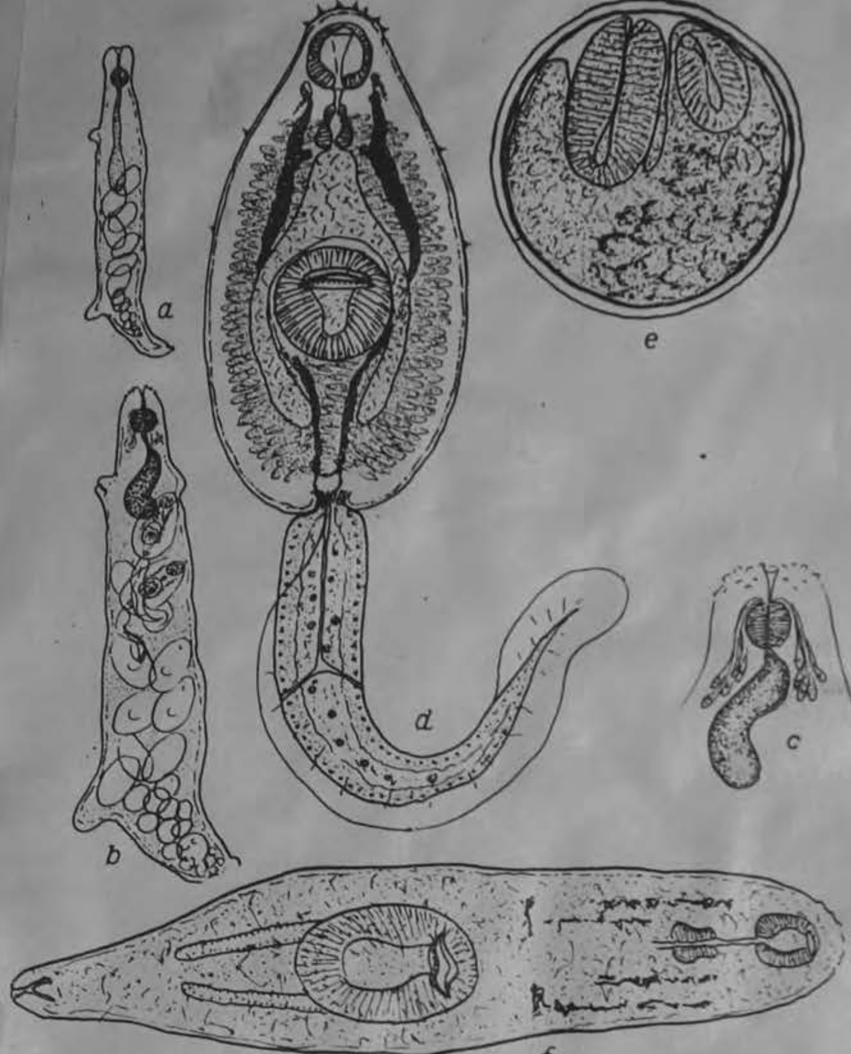


Abb. 1a—f. *Psilochasmus oxyurus* (CREPLIN 1825, LÜHE 1909). a Junge Redie; b adulte Redie; c Vorderende der Redie mit Pharynx und Darm; d Cercarie; e encystierte Metacercarie; f aus der Cyste befreite Metacercarie. Alle Stadien aus *Littoridina australis*

1925 erstmals von CREPLIN in Deutschland gefundenen Art, *Psilochasmus oxyurus*, so daß ein Zweifel an der Zugehörigkeit auch der argentinischen Exemplare zu dieser von CREPLIN beschriebenen Art nicht aufkommen kann.

Von den bisher veröffentlichten Zeichnungen des adulten Wurmes ist die von STUNKARD und DUNIHUE (1931) gegebene die beste, doch ist auch hier der sehr charakteristische Bauchsaugnapf nicht richtig dargestellt. Die Öffnung desselben liegt nämlich nicht zentral, wie die Abbildung angibt, sondern stark nach dem Vorderende des Körpers zu verschoben und besitzt eine halbmondförmige und schlitzartige Öffnung, deren Ober- und Unterlippe stark verdickt ist und die man bereits an der Cercarie und noch deutlicher an der Metacercarie beobachten kann (Abb. 1 d, f). Dagegen kommt der kegelförmig gebaute Pharynx in der Zeichnung dieser beiden Autoren gut zur Darstellung.

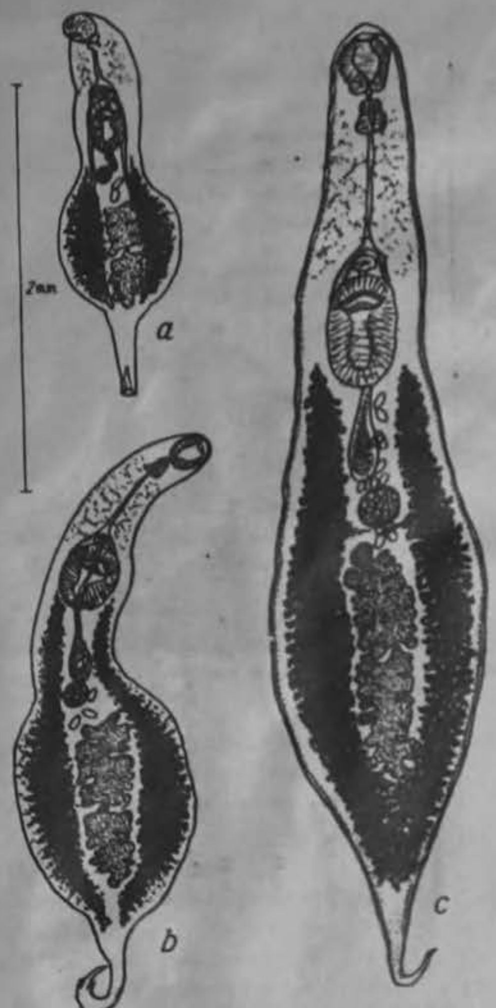


Abb. 2a—c. *Psilochasmus oxyurus* (CREPLIN 1825, LÜHE 1909). a Jüngstes Stadium aus dem Darm von *Dafila spinicauda*, man beachte das noch nicht völlig ausgestülpte Hinterende; b älteres Stadium mit bereits ausgestülptem Endstachel aus dem Darm von *Dafila spinicauda*; c fast erwachsenes Stadium aus dem Darm eines Hühnchens (Fütterungsversuch)

Die Körpermaße sind aus der Tabelle 1 zu entnehmen, die auch die von den verschiedenen Autoren angegebenen Befunde vergleichend wiedergibt. Ohne Zweifel sind die Verschiedenheiten der Maße auf ver-

Stephanoprora denticulata (Rudolphi, 1802) Odhner, 1910

Summary. A new large-tailed echinostome cercaria with 22 collar spines and 36 flame cells in all has been experimentally connected with *Stephanoprora denticulata*. Chickens serve as suitable definitive laboratory hosts wheras *Actitis macularia* is the natural definitive host. Freshwater fish, *Lebistes reticulatus*, are the second intermediate hosts. The synonymy of the species has been discussed and there is a proposal for the rejection of the genus *Beaverostomum*. There is also a key for the separation of the large-tailed echinostome cercariae.

FROM NASIR AND SCORZA, 1968

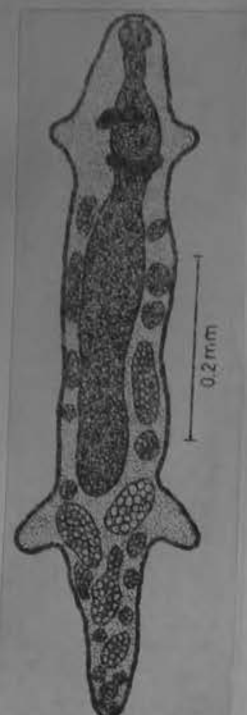


Fig. 1. Redia of *Stephanoprora denticulata*

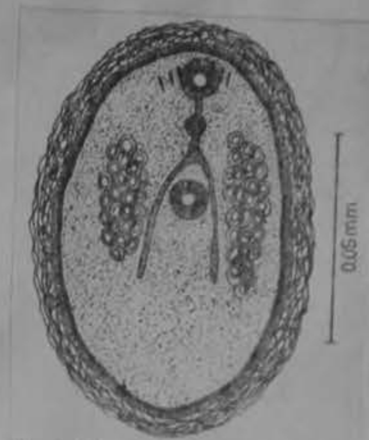
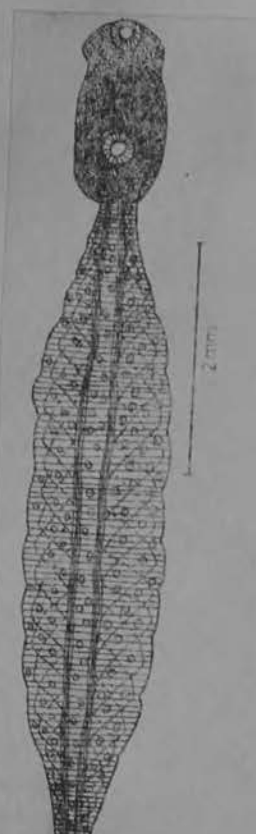


Fig. 4. Metacercaria of *S. denticulata*



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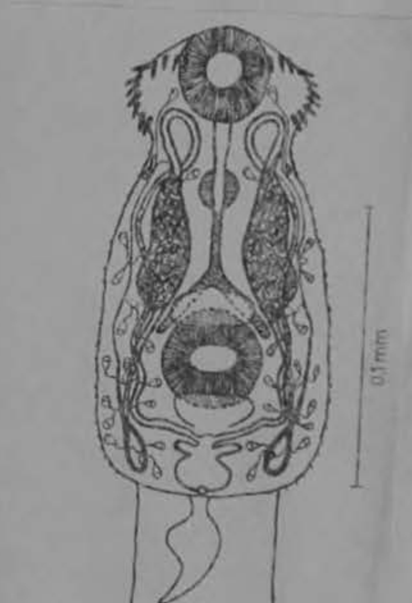

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Fig. 2. Cercaria of *S. denticulata*, showing general appearance
Fig. 3. Cercaria of *S. denticulata*, showing internal organization

Stephanoprora paradenticulata Nasir & Rodriguez, 1969

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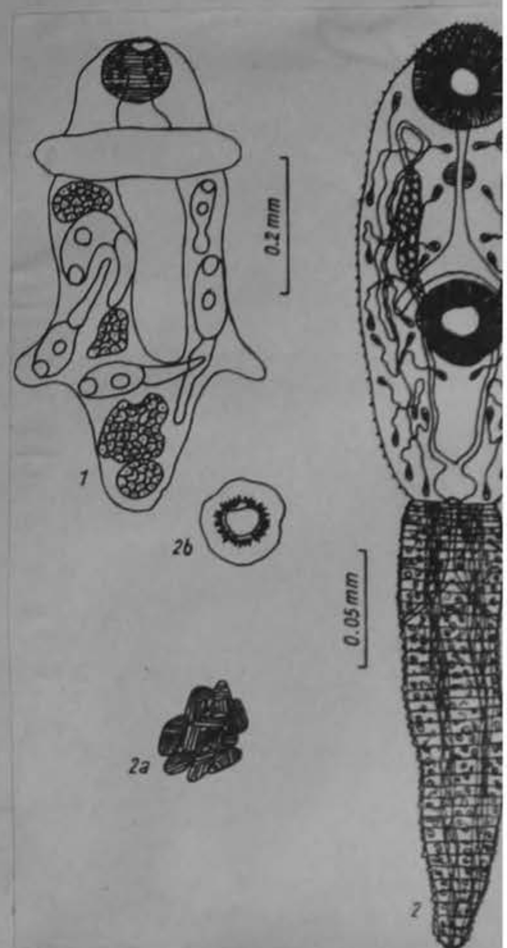
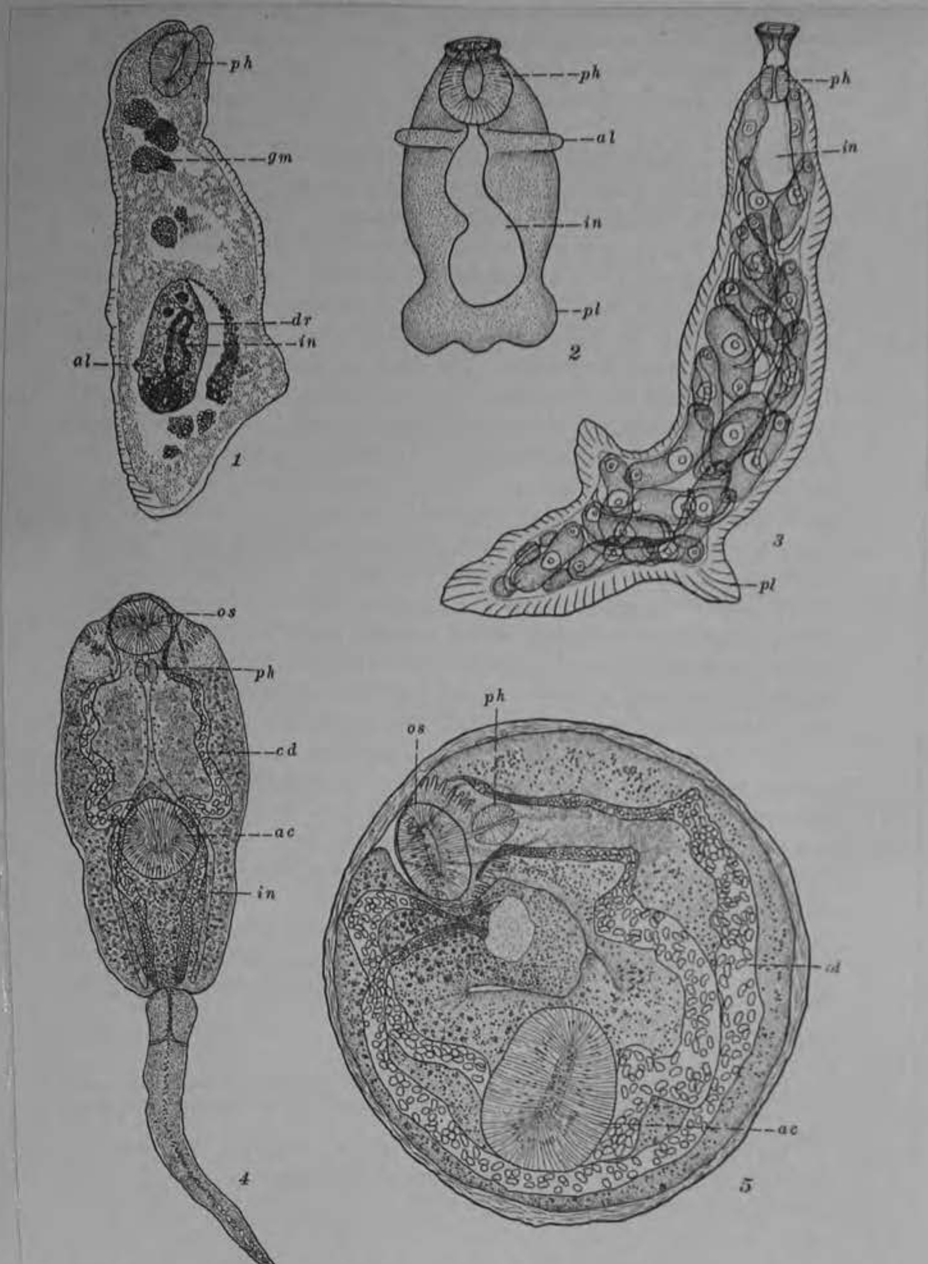


Himasthla quissetensis (Miller & Northup, 1926)



Final host: Larus argentatus, herring gull
Eggs develop slowly.
Cercariae develop in rediae in Nassa obsoleta

Reference: Stunkard, H.W. 1938. Biol. Bull, 75:145-164

Metacercariae in the gills, mantle and foot of various mollusks

Himasthla militaris (Rudolphi)

(1958)

Timon-David & Jacques Rebecq report the metacercaria of this species encysted in Nereis diversicolor in France.

Experimental infections were established in Larus argentatus mich_aellis. The adults have been reported from various Charadriiformes (Numenius arquata; Arenaria interpres; Calidris meritima).

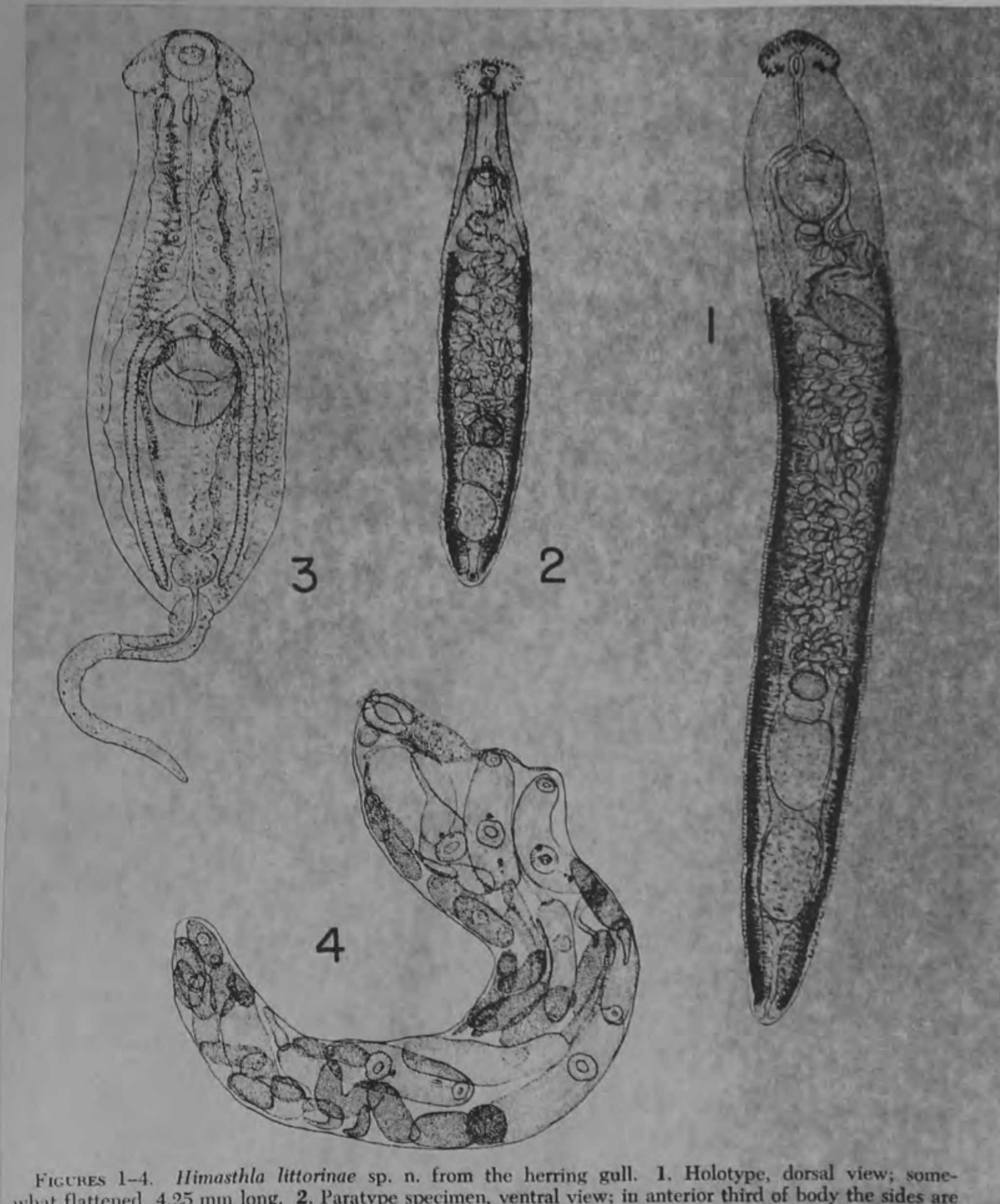
Rediae, cercariae & metacercariae of this species have been ########/#####/####/ described by Zelikman in U.S.S.R. and figured in Skrjabin (1956) without designation of hosts.

THE JOURNAL OF PARASITOLOGY
Vol. 52, No. 2, April 1966, p. 367–372

THE MORPHOLOGY AND LIFE HISTORY OF THE DIGENETIC TREMATODE, *HIMASTHLA LITTORINAE* SP. N. (ECHINOSTOMATIDAE)*

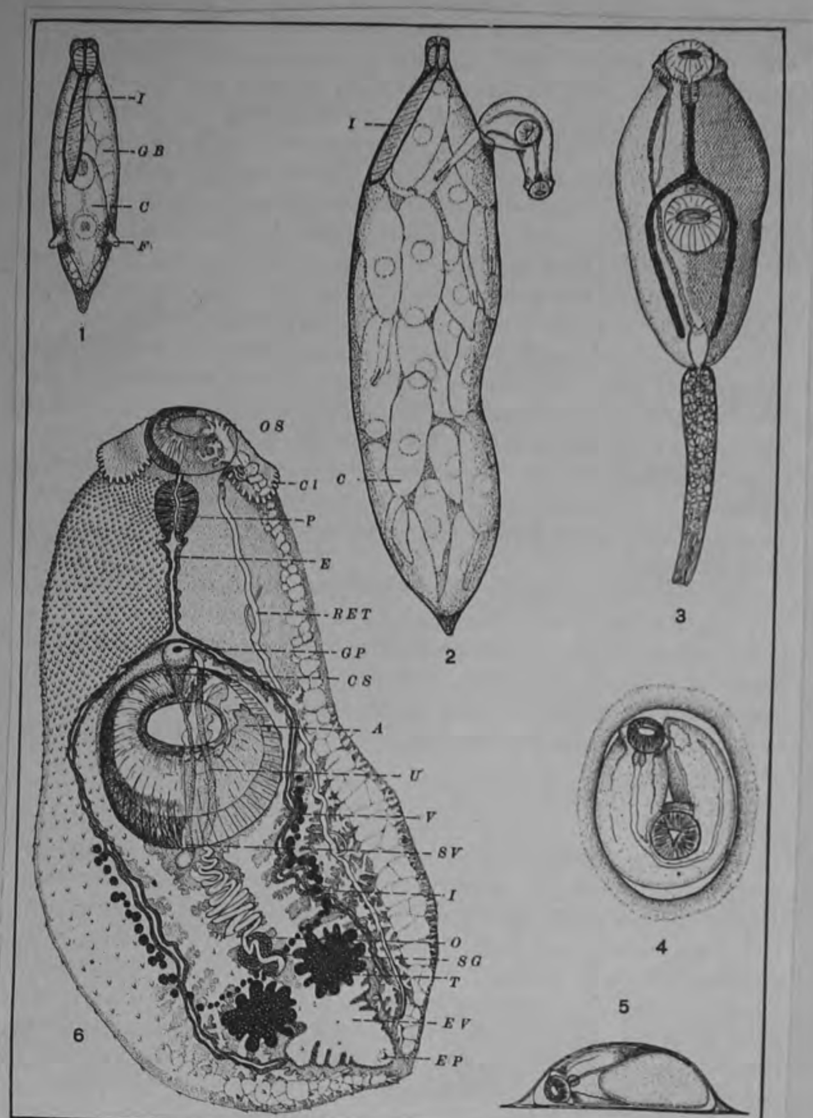
Horace W. Stunkard
The American Museum of Natural History, Central Park West at 79th Street, New York

ABSTRACT: The asexual generations of an echinostome trematode were found in the hemal sinuses of the marine snails, *Littorina saxatilis* and *Littorina obtusata*, in the region of Woods Hole, Massachusetts. The cercariae develop in rediae and after emergence encyst in bivalve mollusks. *Mytilus edulis* and *Mya arenaria* were employed as experimental hosts. The metacercariae developed to sexual maturity in the intestine of laboratory-reared herring gulls, *Larus argentatus*, and the worms are described as a new species, *Himasthla littorinae*. Successive stages in the life cycle are figured.



FIGURES 1–4. *Himasthla littorinae* sp. n. from the herring gull. **1.** Holotype, dorsal view; somewhat flattened, 4.25 mm long. **2.** Paratype specimen, ventral view; in anterior third of body the sides are curved ventrad forming a shallow trench; 2 mm long; same magnification as Figure 1. **3.** Cercaria, ventral view; outline from fixed and stained specimen, 0.65 mm long, details from sketches of living worms. **4.** Redia with developing cercariae; specimen 1.42 mm long.

Parorchis avitus (Linton, 1914)



SUMMARY

The life history of *Parorchis avitus* has been experimentally traced. The cercariæ occur in the marine snails, *Urosalpinx cinereus* and *Thais* (*Purpura*) *lapillus*. Adults have been obtained from the cloaca of the common tern, *Sterna hirundo*, and the roseate tern, *Sterna dougalli*, after feeding the young birds with encysted larvæ.

It has been shown that a specific secondary intermediate host is not essential for the completion of the life history; only a means of transference is necessary.

Additional morphological differences between *Parorchis avitus* and *Parorchis acanthus* are described.

Reference: Stunkard, H.W. & Cable, Raymond 1932
Biol. Bull. 62: 328-338.

Rees – Parasit. 31 – 1939 – believes P. avitus = P. acanthus & that Cercaria sensifera is a synonym of C. purpurae. in Nucella lapillus

Angel, L. Madeline 1954
Parorchis acanthus var. australis n. var., with an account of its life cycle in South Australia
Trans. Roy. Soc. S. Australia 77: 164–174.

Life history of <u>Cathaemasia hians</u> Rud.

Adult in throat of black stork, *Ciconia nigra*.

Eggs hatch at once into ciliated miracidia which invade *Planorbis planorbis*, *P. contortus*, *P. septemgyratus*, and *Lymnaea palustris*.

Sporocysts produce mother rediae after 10-12 days. Daughter rediae move toward midgyt glands. Cercariae appear after 37 days (if temperature is over 26 C)

Cercariae :: *Cercaria choanophila* U.Szidat, 1936, with evanescent crown of 47 spines (showing Cathaemasia to be an aberrant echinostome genus)

Metacercariae encysting in "choanen" of frog, *Rana esculenta*.

Reference: Szidat, L. 1939 Zeit.Parasit., 11:239-283.

LIFE HISTORY OF CATHAEMASIA HIANS Rud.
from Szidat, 1939

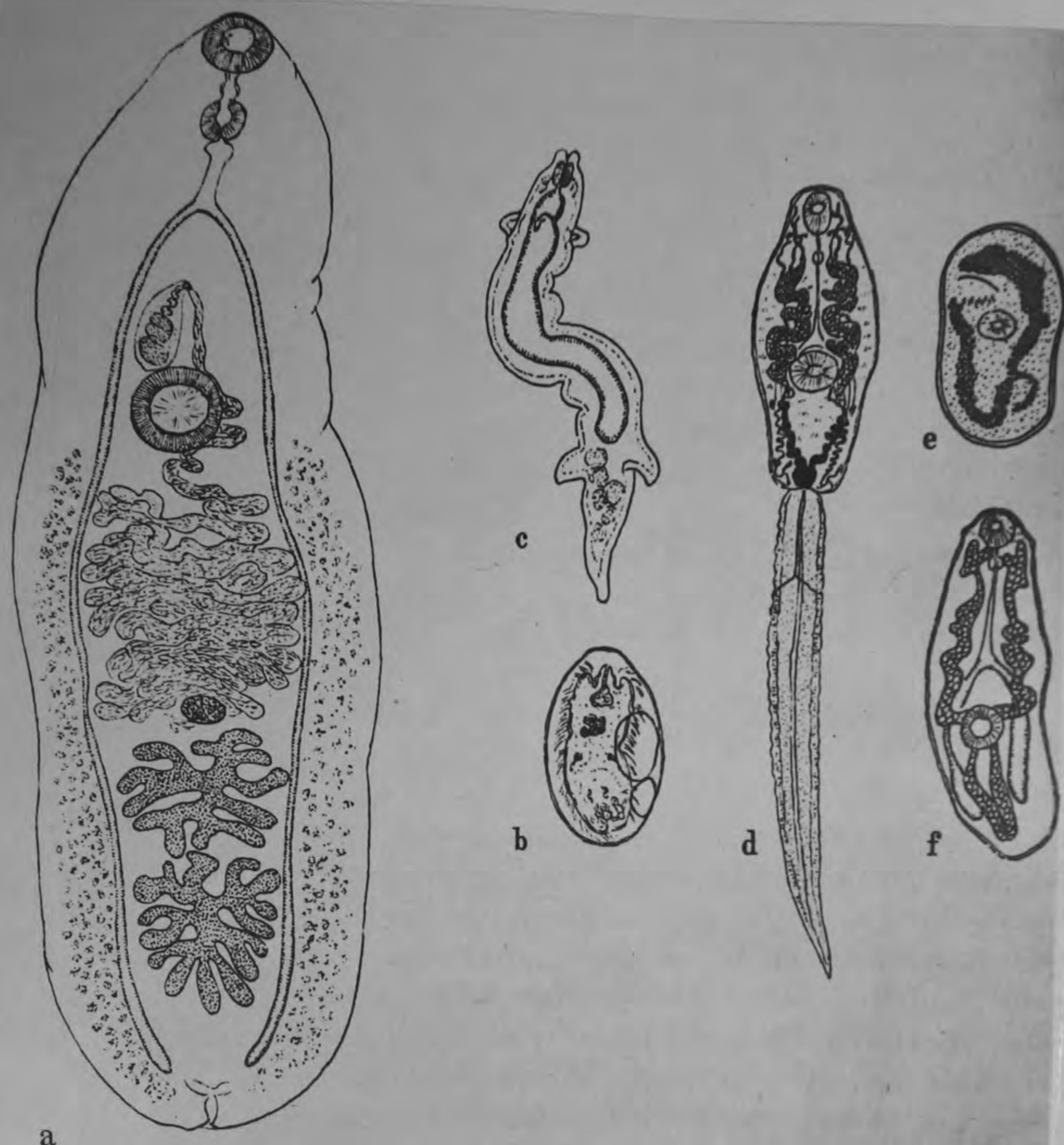
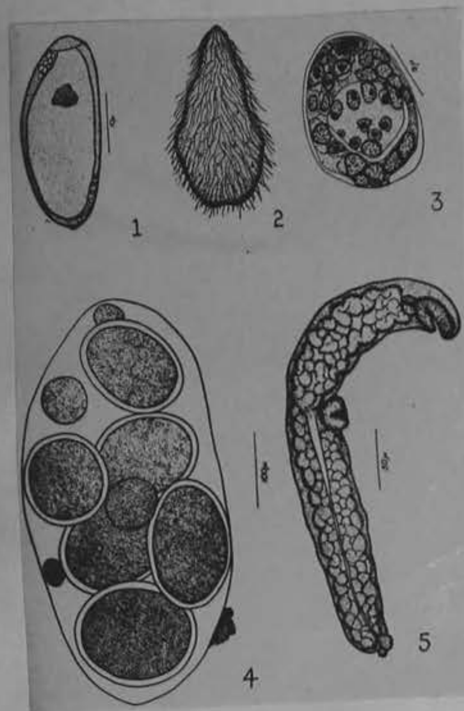
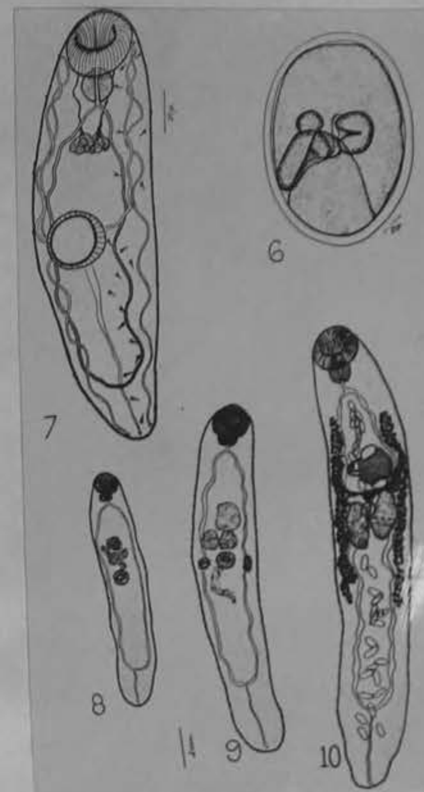


Abb. 3 a bis f. *Cathaemasia hians* RUD. a Erwachsener Wurm aus dem Schlund e schwarzen Storches *(Ciconia nigra L.)*; b reifes Ei mit Miracidium; c junge Tochterr aus *Planorbis planorbis* L.; d reife Cercarie *(Cercaria choanophila* U. SZIDAT) aus *Plano planorbis* L.; e encystierte Metacercarie aus den Choanen des Wasserfrosches *(R esculenta)*; f aus der Cyste befreite Metacercarie.

ECHINOSTOMIDAE

<u>Tamerlania</u> <u>bragai</u> Santos, 1934





From Maldonado, 1945
J. P. 31: 306-314

From Kingston, 1965

Eucotylidae

Tanaisia zarudnyi

Life History

Sexually mature *Tanaisia zarudnyi* contain several hundred small, fully developed eggs in the part of the uterus anterior to the testes, as well as developing eggs in the uterus posterior to the testes (Fig. 14). Fully developed eggs are oviposited by the worm and pass out of the kidneys and body of the host with the urinary excretions. The eggs do not hatch until ingested by molluscs. They are resistant to low temperatures (−15 °C for 30–60 days, −49 °C for 24–48 hours) and remain unhatched and viable for periods exceeding 3 years at 2 °C. The eggs were fed to 12 species of terrestrial snails and slugs. Hatching occurred in each species, and living miracidia were seen in the gut lumina of dissected snails and slugs 20 minutes to 3 hours after exposure (Table I).

TABLE I

Summary of exposures of snails and slugs to eggs of *Tanaisia zarudnyi* from ruffed grouse

Species of snail or slug	Eggs hatched	Free miracidium	No. molluscs examined no. infected	No. days before examination
Deroceras reticulatum (Muller)*,†	+	−	10/0	56–76
Triodopsis multillineata (Say)*,‡	+	+	3/0	62
Anguispira alternata (Say)*,†	+	+	76/30	45–365+
Succinea ovalis (Say)*,†	+	+	7/1	71
Zonitoides arboreus (Say)†	+	+	9/0	20–26
Discus cronkheiti (Newcomb)†	+	−	9/0	18–27
Arion circumscriptus (Johnston)‡	+	+	7/0	23–24
Stenotrema fraternum (Say)*,†	+	−	5/0	49
Stenotrema hirsutum (Say)*,‡	+	+	—	—
Stenotrema monodon (Rackett)*,‡	+	−	—	—
Allogona profunda (Say)*,‡	+	−	—	—
Lamellaxis gracile (Hutton)*,‡	+	+	4/0	33–54

*Laboratory reared.
†Found in Algonquin Park (17).
‡Not found in Algonquin Park (17).

The unhatched miracidium, just before hatching in the snail gut, shows a slow steady beating of the flame cells and occasional body contraction and external ciliary movement. With the release of the operculum, the vitelline membrane pushes forth through the opercular opening. Activity of the flame cells increases as water enters the egg and the miracidium emerges from within the vitelline membrane. Emerged miracidia were observed swimming in the gut and body fluids of dissected snails; they are plastic in body form and often the sides of the body are indented, showing the location of the boundaries of the epidermal plates. While swimming, the miracidia frequently bend, bringing the posterior and apical ends into contact; often they apply the apical end bearing the stylet to a piece of snail tissue and without turning the body, push against the tissue, this action being accompanied by a rapid beating of the cilia.

Larval stages of *T. zarudnyi* were found in snails, *Anguispira alternata* and *Succinea ovalis*, 45 to 365 days after they were fed eggs. Development of the parasite was followed in more than 30 infected, laboratory reared *A. alternata*.

The mother sporocyst and early daughter sporocyst of *T. zarudnyi* have not been observed. The study of daughter sporoycsts and unencysted cercariae was begun the 45th day after infection in snails maintained at about 75 °F. The daughter sporocysts show through the clear serosa covering the digestive gland of the snail and are interspersed between the still intact follicles of this organ. They are most numerous in that region of the digestive gland of the snail in which the proximal end of the intestine enters this tissue. In heavy infections much of the digestive gland of the snail is destroyed and replaced by parasite tissue. The sporocysts are elongate, sacculate bodies and show little activity.

Forty-five-day-old daughter sporocysts contain a few cercariae at approximately the same stage of development. The cercariae are weakly active, distomate, and brevicercous; internal structures are difficult to discern owing to many large, granular, subcuticular glands. Under slight pressure the contents of these glands are extruded through the cuticle, though no pores were seen in the cuticle. Fully developed cercariae encyst within the daughter sporocysts, in individual thick-walled hyaline cysts. The earliest encysted metacercariae were seen at about 45 days after infection.

By 60 days after infection, most cercariae are encysted, within the now defunct daughter sporocysts. Metacercariae replace much of the snail's digestive gland and are most numerous in that part surrounding the anterior gut. Between 1000 and 4000 metacercariae may be found in one *A. alternata*, where they remain viable and infective for more than a year. Occasionally encysted metacercariae are seen lying next to unencysted cercariae in the same sporocyst.

When encysted metacercariae are removed from the snail, they remain alive at room temperature for at least 30 hours. Such metacercariae are stimulated to greater activity when placed on a warm stage at 104 °F; conversely, cooling slows their activity. At room temperature, the addition of 5% saline momentarily activates the encysted metacercariae, but they soon shrink to about one-half of their former volume and become immobile. When the concentrated saline is exchanged for distilled water, the metacercariae swell, become active again, and eventually fill the available space within the cysts. Obviously the cyst wall is permeable to water.

In preliminary in vitro studies, the encysted metacercariae were treated with natural and artificial gastric and digestive fluids. These substances neither digested the cyst wall nor caused the metacercariae to excyst. Encysted metacercariae of *T. zarudnyi* were fed to chickens of various ages (1), immature and mature ruffed grouse, immature and mature pheasants, and white-throated sparrows to determine infectability and to recover excysted forms.

No parasites were found in the ureters of chickens, pheasants, and white-throated sparrows that were examined 3 hours to 16 days after they were fed metacercariae (Table II). A few dead, encysted, yellow-stained metacercariae were recovered from the gizzard and duodenum of chickens examined 3 hours after they were fed the metacercariae. Survival of the metacercariae in the intestine of chickens and pheasants was tested by injection of 200 to 4000 encysted metacercariae into the duodenum of anesthetized chickens and pheasants in which the duodenum was tied off from the gizzard. A number of excysted, active metacercariae were recovered along the length of the gut of chickens 3–7 hours later, but none had made its way into the ureters of these birds 14–24 hours after inoculation (Table II).

Some of the excysted metacercariae from the intestine of inoculated chickens were inoculated *per ano* (2) into white-throated sparrows. The birds were prevented from defecating and were examined 14 hours and 4½ days later with no worms being found in the ureters (Table II).

Ruffed grouse of various ages were fed encysted metacercariae, frequently in repeated feedings, and were examined 6 hours to 170 days later. One ruffed grouse, 6 weeks of age, was fed cysts from six heavily infected *A. alternata* and from another infected snail 7 days later; when examined 6 hours after this final feeding, 21 immature *T. zarudnyi* were recovered from the ureters and renal calyces. These flukes showed little development beyond that seen in the excysted metacercariae recovered from the gut of inoculated chickens. No flukes were recovered from the gut. None of the other ruffed grouse exposed was infected (Table II).

Presumably only young ruffed grouse are infectable, but if so, the infection may persist for some time, since natural infections are found more frequently in older birds. The negative results with birds other than ruffed grouse suggest a host specificity.

Description of Stages in Life Cycle

The Egg (Figs. 1–3)

The eggs of *T. zarudnyi* taken from the distal end of the uterus are dark brown, thick-shelled (ca. 0.003*), operculate, asymmetrical ovals measuring 0.038 to 0.045 by 0.022 to 0.027. They contain fully developed miracidia at oviposition. The eggs are triangular in cross section and the eggshell surface is roughened with coarse vermiculations. The opercular edge is serrate. The shell terminates at its abopercular end in a small rounded knob. Within the shell, surrounding the miracidium, are numerous, yellowish, refractile granules forming the opercular cushion at the anterior end of the egg; these granules are also distributed within the vitelline membrane along the sides and at the posterior end of the egg. The eggs are impermeable to water.

The Miracidium (Figs. 2 and 4)
Miracidia of *T. zarudnyi* within, and hatched from eggs, have been studied. hey are elongate, pyriform, and ciliated, measuring about 0.030 before itching, and from 0.037 to 0.040 after hatching. The miracidia are pointed their apical ends, in which a blunt stylet (0.016 to 0.019) is situated. Interilly a triangular fibrillar mass surrounded by a glandular sac is located

Ducts of four pairs of postpharyngeal glands are situated on the anterior margin of, and lateral to, the midline of the oral sucker. Four pores on each side of the midline empty the ducts, which run posteriorly and dorsally to the oral sucker, where they diverge laterally. The ducts arise from eight dorsal, granular, uninucleated, pyriform glands situated immediately anterior to the ventral sucker. The ducts contain a clear, refractile, yellow-green material which is extruded through the pores as compact globules that are insoluble in water and saline. The glands are lacking, or empty, in the excysted metacercariae, which suggests that they function in the excystation process.

Living excysted metacercariae, 0.40 to 0.43 by 0.11, were collected from the gut of chickens 3 to 7 hours after intraduodenal inoculation of metacercarial cysts. They were frequently found mixed with food in the gut lumen but more often were adjacent to, or in contact with, the gut epithelium, where they were attached to the intestinal villi by their ventral suckers. They contracted and extended themselves with worm-like movements and twisted the forebody on the longitudinal axis. The oral sucker is subterminal, measuring 0.050 by 0.060. The ventral sucker, 0.050 by 0.045, is 0.230 distant from the anterior end. The pharynx measured 0.030 by 0.032. Fixed excysted metacercariae are larger than the cercariae, and measure as follows: length, 0.32–0.33; width, 0.09; oral sucker, 0.033 to 0.036 by 0.039 to 0.042; ventral sucker, 0.030 to 0.036 in diameter, 0.10 to 0.11 from anterior extremity; caecal union, 0.28 from anterior extremity. The bodies of the worms are much clearer than the cercariae and encysted metacercariae, and the ducts and terminal pores of the anterior glands noted in the encysted metacercariae are still clearly visible. The glands themselves, when still visible, are located about 0.17 from the anterior extremity of the worm. The gut in these specimens is already fused posteriorly; this was not evident in the cercariae and metacercariae. Some metacercariae showed an oesophageal dilation posterior to the pharynx, which was lacking in other specimens. The tubules of the excretory system are more apparent than in the previous stages. The excretory bladder extends forward from the subterminal excretory pore as a narrow thin-walled tubule; a short distance anterior to the excretory pore, it enlarges into an elongate, lens-shaped bladder surrounded by circular muscles, which give this portion of the bladder a thicker appearance than the remainder; this muscular portion of the bladder pulses rhythmically with the excretory pore. Anterior to this muscular section, the excretory bladder narrows again to a thin non-muscular tubule. Immediately in front of the ventral sucker, the bladder divides at right angles into two laterally directed branches which arise from the sides of a small vesicle. Each lateral branch extends from this vesicle toward the margin of the body, but before reaching it, the tubule turns anteriorly and forms a convoluted loop; it returns posteriorly to the level of the lateral branch, where it again turns laterally and divides almost immediately into an anterior and a posterior branch. In some specimens, the anterior branch divides again after a short distance and both branches extend into the region of the oral sucker. The posteriorly directed branch was not seen to branch again. Flame cells at the internal origins of the excretory system have been seen within the body of the excysted metacercariae, but it has been difficult to determine their number or pattern.


6


5


4


2


1

The excysted metacercariae of *T. zarudnyi* resemble the cercariae and the encysted metacercariae in that the ventral sucker is retained and the ducts of the anterior glands are still evident. They are greater in size, however, and the genital primordia are visible in stained specimens.

Twenty-one active, immature *T. zarudnyi* were recovered from the ureters and kidneys of a 6-week-old ruffed grouse 6 hours to 1 week after it was fed the encysted metacercariae. Fixed specimens (Fig. 11) were about the same size and at the same stage of development as were those just described.

Discussion of the Life Cycle of Tanaisia zarudnyi

The life cycle of *Tanaisia zarudnyi* from ruffed grouse is similar to that of *T. bragai* (Santos, 1934) Byrd and Denton, 1950, a parasite of pigeons and land snails in Puerto Rico (14, 15). Both worms occur in the ureters and associated tubules of the kidneys of their avian hosts. The vitellaria in mature *T. zarudnyi* do not extend into the ovarian region (3) as in *T. bragai* (3, 14, 15, 21, 26), and the cuticular scales of the two differ (5, 6). The eggs of *T. zarudnyi* are about twice as large as those of *T. bragai* (14), and the eggshell of the latter apparently lacks surface vermiculations. Eggs of both species presumably pass out with the kidney excretions. Eggs of *T. zarudnyi* remain viable for extended periods and are resistant to extremely low temperatures. The eggs of both species hatch only in the gut of molluscs. The miracidium of *T. zarudnyi* is somewhat larger than that of *T. bragai* and possesses a stylet, which is noted only as a "snout-like projection" in the latter species (14); otherwise the miracidia of both are similar. *T. zarudnyi* develops in the land snails *Anguispira alternata* and *Succinea ovalis*, whereas *T. bragai* develops in the unrelated *Subulina octona* in Puerto Rico (14, 20). The mother sporocysts of *T. bragai* were observed as early as the fourth day after infection, and developing daughter sporocysts free of the mother sporocyst, 4 to 6 days later (14). Daughter sporocysts of *T. zarudnyi* require at least four times as long for their development. Cercariae of *T. zarudnyi* and *T. bragai* are similar in size and morphology, and both encyst within the daughter sporocysts, forming metacercariae. The snail hosts, thus, may be considered as functioning as both first and second intermediate hosts. The metaceracarial cysts of both species are similar in size,* and enclose mobile metacercariae. Metacercariae of *T. bragai* were found as early as the 30th day after infection, but those of *T. zarudnyi* not until the 45th day. Metacercariae of *T. zarudnyi* apparently increased in size while they were within the cyst, whereas those of *T. bragai* apparently decreased in length. Chickens, pheasants, white-throated sparrows, and mature ruffed grouse proved to be refractory to infection with the encysted metacercariae of *T. zarudnyi per os*. However, one immature ruffed grouse became infected after it was fed several thousand metacercariae. The worms resembled in size and state of development the excysted metacercariae recovered from the gut of inoculated chickens. Maldonado was able to produce infections in young pigeons and to follow the rate of development of the parasite, which became sexually mature when approximately 1.25 mm in length, about 2 weeks after exposure of the host bird (14).

*The cyst of *T. bragai* (14) is reported as being 146 by 36 μ; the latter figure is obviously a typographical error, as the illustration of the cyst shows it to be nearly spherical.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15


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EUCOTYLIDAE

Fasciola hepatica

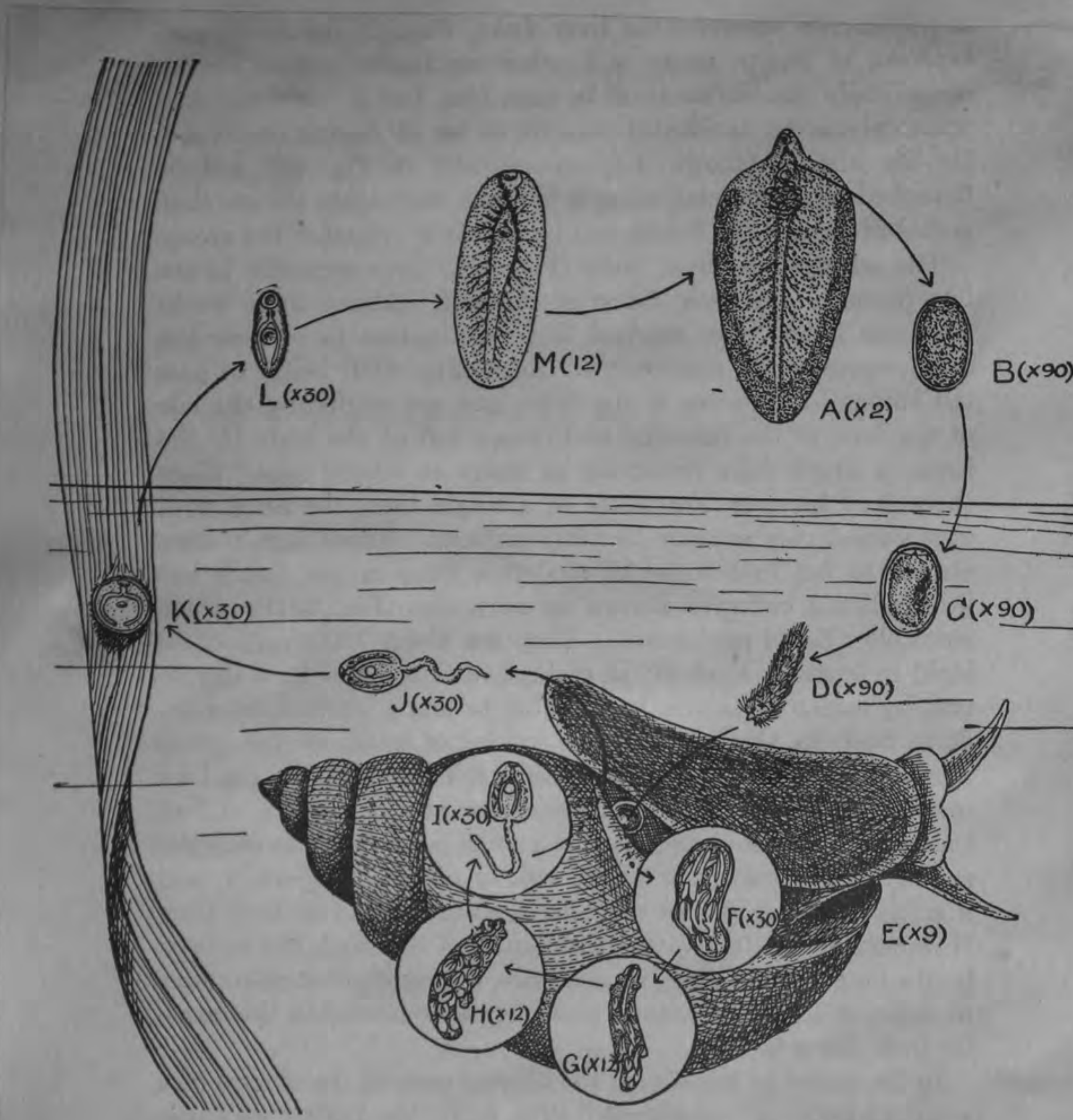
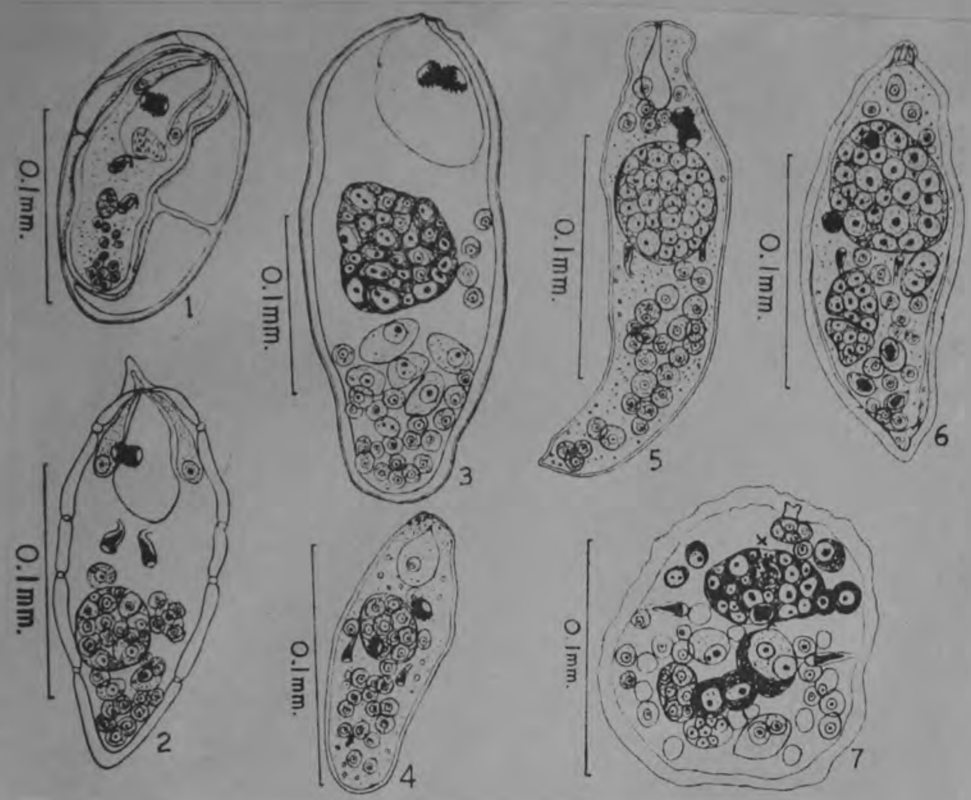


FIG. 63. Life history of liver fluke, *Fasciola hepatica*; *A*, adult in liver of sheep; *B*, freshly passed egg; *C*, egg with developed embryo, ready to hatch in water; *D*, ciliated embryo in water, about to enter pulmonary chamber of snail (*E*); *F*, sporocyst containing rediæ; *G*, redia containing daughter rediæ; *H*, redia of 2nd generation containing cercariæ; *I*, cercaria; *J*, same, having emerged from snail into water; *K*, cercariæ encysted on blade of grass; *L*, cercaria liberated from cyst after ingestion by sheep; *M*, young fluke developing in liver of sheep.

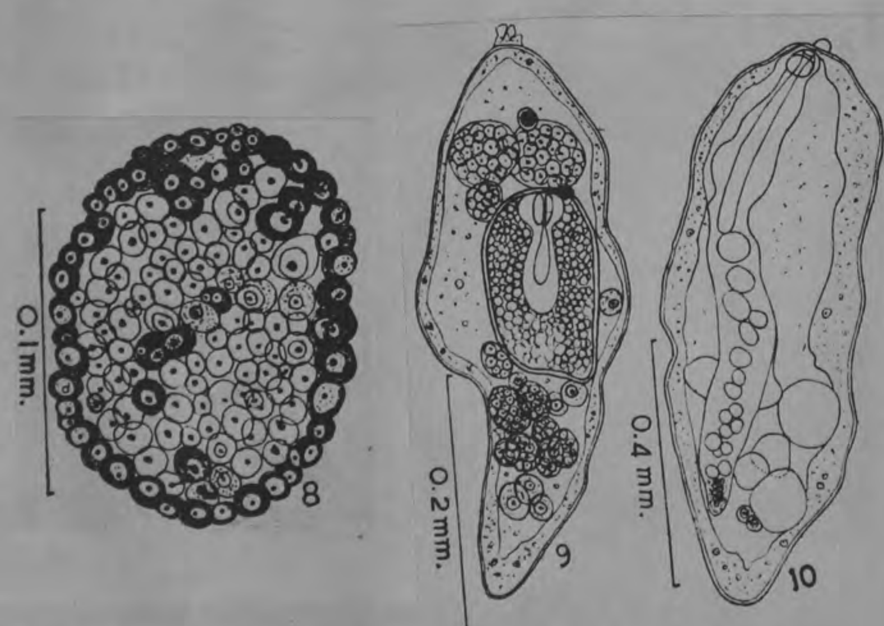
From Chandler's text

For cercaria see Reese, 1932
Proc. Zool. Soc. London
Kuntz, 1951 Trans Amer. Micro. Soc
70: 95-118.

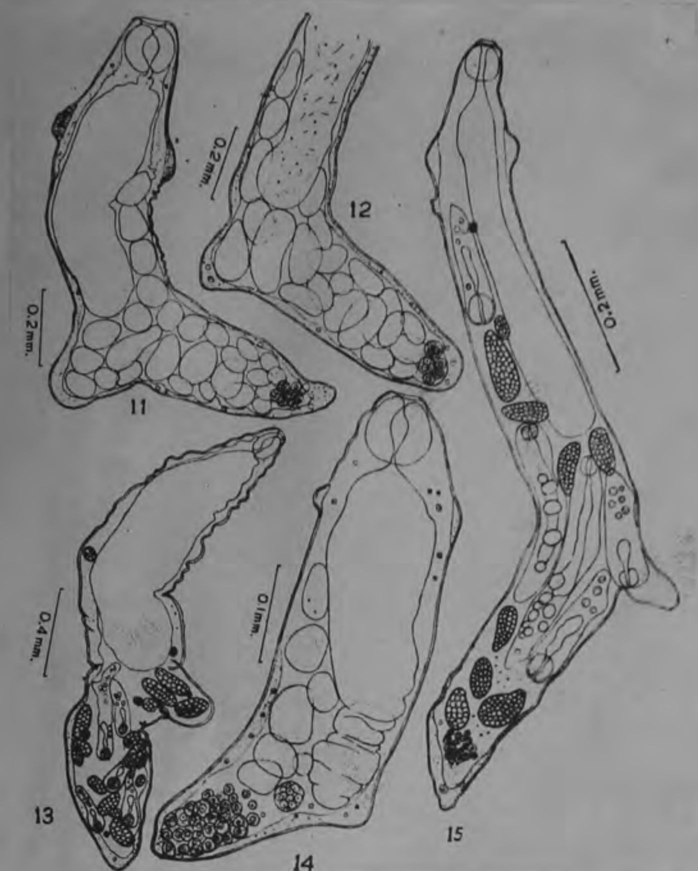
Fasciola indica Verma, 1953



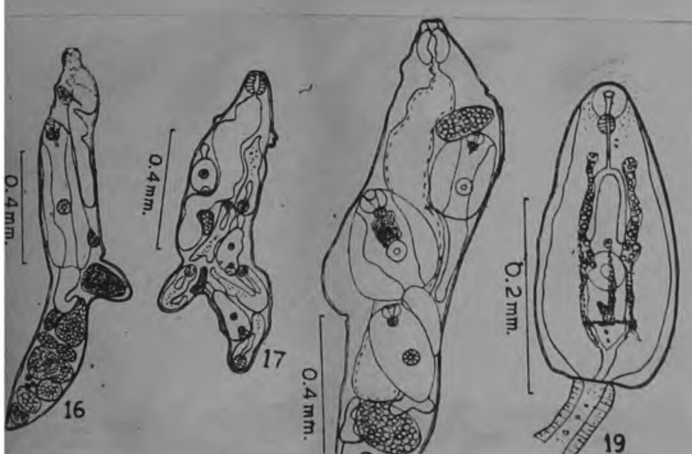
Figs. 1—7. 1. Miracidiumof *Fasciola indica*, inside the egg, showing germainal mass and germinal cells. Fig. 2, 3. Miracidia showing the germinal masses and cells, as seen after being stained with Neutral red (2) and Brilliant cresyl blue (3). 4. Sporocyst recovered after two days of infection of the snail (from the mantle wall). 5. Three days old sporocyst from the mantle wall. 6. Five days old sporocyst from the foot of the smail. 7. Eleven days old sporocyst, in acontracted condition, from the mantle cavity, showing the disintegrating eye-spots (×) also.

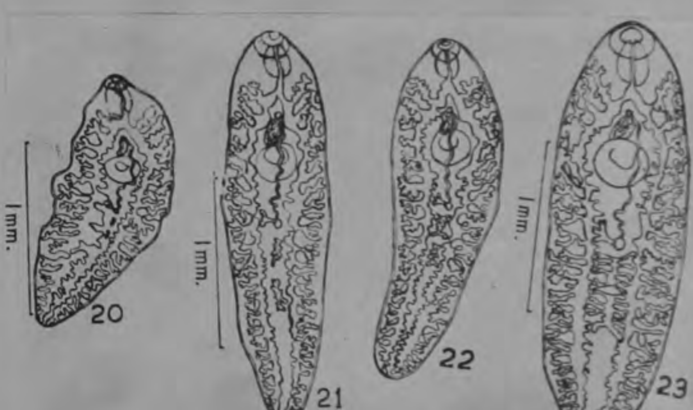


Figs. 8—10. 8. A germinal mass dissected out of the sporocyst showing the formation of a redia. 9. Twenty days old sporocyst with a developing redia, germinal masses, cells and the presisting eye-spots. 10. Twenty-nine days old sporocyst with a fully developed redia having its germinal material also.



Figs 11—15. 11, 12. Mother-rediae obtained on 35th day after infection, showing the entire posterior half of the body packed with germinal masses and cells. 13. Mother-redia obtained on the 48th day (in winter) showing fully developed daughter-rediae and germinal material. 14. A daughter-redia dissected out of the body of the mother to show the dividing germinal masses and cells. 15. Mother-redia on the 18th day (summer) showing daughter-rediae and germinal material.





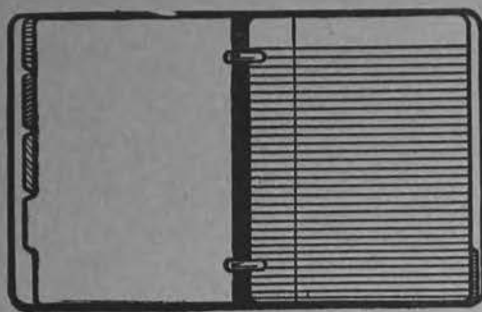
Figs. 16—19. 16. Mother-redia on 59th day (winter) with developing cercariae and germinal material. 17. Mother-redia with both daughter-rediae and cercariae, and two germinal masses only. 18. Mother-redia on 60th day with cercarie, some cercariae have gone out of the body of the mother. 19. Cercaria showing the rudiments of reproductive organs etc.

Figs. 20—23. 20. Young fluke (1.58 × 0.68 mm) from guinea pig, showing rudiments of testes, ovary, Mehlis' gland, uterus, and cirrus etc. 21, 22, 23. Young flukes from guinea pig, showing different stages of the development of reproductive and digestive organs.

FROM TANDON, 1970

FASCIOLIDAE

LOOSE LEAF INDEX



ABLE INDEX
DERS, SUITABLE
SCHOOL OR
MERCIAL USE.

IDEAL FOR CLASSIFYING, OR SEPARATING STUDIES, VARIOUS SUBJECTS OR MISCELLANEOUS DATA.

Telephone

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Class

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Year

SUBJECTS

CLASS SCHEDULE

PERIOD		FIRST	SECOND	THIRD	FOURTH	FIFTH	SIXTH	SEVENTH	EIGHTH
AY	COURSE								
	INSTRUCTOR								
DAY	COURSE								
	INSTRUCTOR								
ESDAY	COURSE								
	INSTRUCTOR								
SDAY	COURSE								
	INSTRUCTOR								
Y	COURSE								
	INSTRUCTOR								
RDAY	COURSE								
	INSTRUCTOR								

According to Palombi, 1934, the life cycle of *Bacciger bacciger* is as follows:

Adults in *Atherina hepsetus* L.
A. boyeri

Eggs are laid, hatch into ciliated miracidum which enters lamellibranch molluscs: *Tapes decussatus* L., *T. pullaster* Montagu, *T. phillippinarum* Adams & Reeve. *T. aureus* Gmelin, *Donax vittatus* DaCosta, *Pholas candida* L.

Long sporocysts produce setiferous cercariae which swim about and penetrate amphipods: *Erichtonius difformis* (Edw.) where the metacercaria is encysted.

The *Bacciger bacciger* of Nicoll, 1914 Palombi considers to be a new species: *B. nicolli* Palombi, 1934 In *B. nicolli* the intestinal bifurcation is distant from the acetabulum, the seminal vesicle is ~~bilobed~~, ~~and~~ not bilobed but simple, and the host is *Atherina presbyter* Cuv.

The cercaria of *Bacciger bacciger* has been known (according to Palombi) as:

Cercaria lata Lespec, 1857
Cercaria pectinata Huet
C. lutea Giard

Life cycle of <u>Bacciger</u> <u>bacciger</u> (Rud.)
(Fellodistomidae) from Palombi, 1934

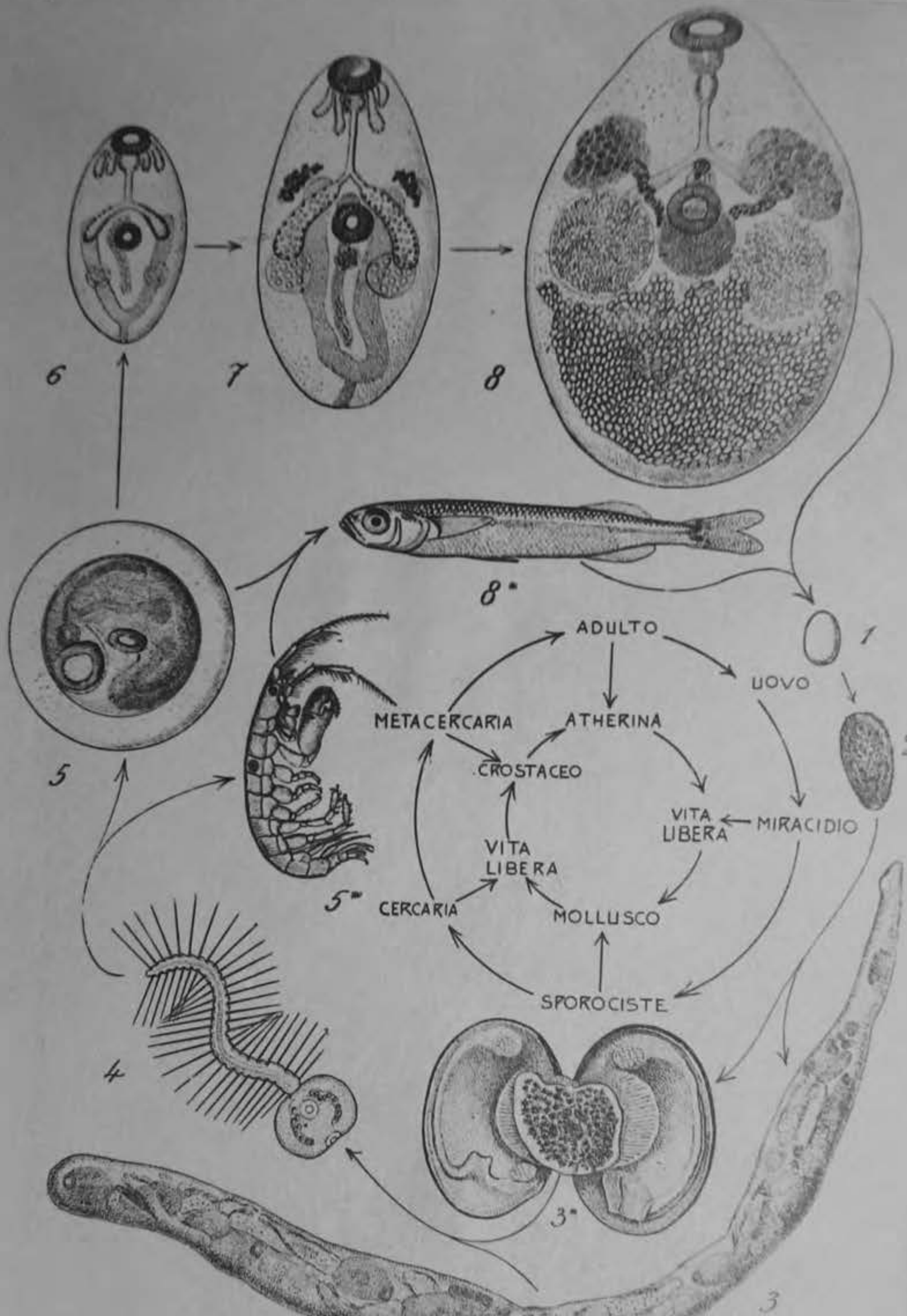


Fig. 33. — Ciclo biologico di *Bacciger bacciger* (Rud.).
1. uovo × 360; 2. miracidio × 156; 3. sporociste × 40; 3*. *Tapes decussatus* L. infestato dalle [illegible] cisti × 0.8; 4. cercaria × 70; 5. metacercaria × 100; 5*. *Erichtonius difformis* (Edw.) infestato [illegible] tacercaria × 8; 6, 7. stadi di sviluppo del distoma nell'intestino delle *Atherina* [illegible] 8*. *Atherina hepsetus* L. × 0.65.

Burnellus trichofurcatus (Johnston & Angel, 1940) Angel, 1971

Life History

Johnston & Angel (1940) reported that the cyst stage of *Cercaria trichofurcata* had not been found, though a variety of different animals had been tried as intermediate hosts. Since then, a number of further experimental infections have been attempted when cercariae were available, but no cysts have been recovered from any of the experimental animals. We suggested that it was possible that the cyst stage was omitted from the life cycle, and that infection of the fish might occur directly, possibly through the gills or by the alimentary canal.

From time to time, a few very young catfish have been netted in the River Murray. Some of these have been placed in tanks with *Corbiculina angasi* infected with *Cercaria trichofurcata*. The first of these fish (June 1941) did not become infected; the second (2 May 1947 to 5 June 1947) had three young *Mehratrema* in the gut when it died. Five young catfish of the same size (2 inches long, or less) dissected over this period were uninfected. After this, it was not until March 1970, when cercariae and small catfish were available in the laboratory at the same time. Five fish under 2 inches in length were caught on 1 day. The two largest were kept as controls, while the other three were put in a small tank with three infected *Corbiculina angasi*. Two fish died in 12, and the third in 14 days. In their alimentary canals were 46, 71 and 39 immature trematodes, while the two controls had none. The trematodes resembled both *Cercaria trichofurcata* and *Burnellus* sp. found in adult catfish so closely that I have no hesitation in assigning them to the same species.

I did not observe how the infection of the catfish occurred, and have had no further fish and cercariae since then. Johnston & Angel (1940) observed the fish, *Gambusia affinis* and the crustacean, *Cherax destructor* eating *Cercaria trichofurcata*, and it seems reasonable to assume that this is the way *Tandanus tandanus* becomes infected. (Gland cells were still present in the young trematodes, and stained with neutral red *intra vitam*. One wonders what function they perform in the natural life history). It is possible that larger catfish, as they browse on the bottom-dwelling organisms among which are *Corbiculina angasi*, ingest the cercariae accidentally.

Miracidium

Miracidia of *B. trichofurcatus* have never been observed, although eggs have been kept under daily observation for over 3 weeks. Cable (1953, p. 415) stated that miracidial structure was unknown in the Fellodistomatidae; so far as I am aware, this is still the case. It seems relevant, therefore, to report that I once observed free swimming miracidia of *Tandanicola bancrofti*, although I was not able to capture any and so observe their structure. In April 1957, adult *T. bancrofti* were taken from the host and put almost immediately into a refrigerator at 4 °C, in saline. Four days later, the trematodes were examined; they were still alive, and numerous eggs had been laid. The eggs were then kept at room temperature. The following day several miracidia were seen under the dissecting microscope. They were very small, and swam so fast that I was not successful in catching any. Although the eggs were kept under daily observation for 3 weeks, no further free-swimming miracidia were seen. Previously to this, I had observed motile miracidia within the eggs of *T. bancrofti* on four different occasions (November 1941, February 1948, March 1954 and October 1955). The eggs were examined daily. Motile miracidia were seen from the first to the fifteenth day. It is not known whether the eggs were dissected from the trematodes, or whether they were laid in

- OVER -

the dishes and hence, presumably, would have been mature from the first day. Sketches and notes made on the miracidium give the following description: blunted anteriorly, tapered slightly posteriorly; quite long cilia over about the posterior two-thirds of the body (cilia not seen anteriorly); with a head lobe; two, or possibly four, gland cells anteriorly. The miracidium occupied only about half the space within the egg; in the rest of the area were a number of globules.

The egg of *B. trichofurcatus* is of about the same size and general appearance as that of *Tandanicola bancrofti*, and I suggest that the miracidia may follow the same hatching pattern. On three occasions I have attempted, unsuccessfully, to infect *Corbiculina angasi* by placing them in small tanks with eggs of *B. trichofurcatus*. The eggs had been left for 2–3 weeks at room temperature before the molluscs were put with them and the viable ones may already have hatched.

Although study of cercariae from the River Murray was started in this department in 1937, the cercaria of *T. bancrofti* is still not known. If this genus does belong in the Fellodistomatidae as defined by Cable (1953), it is to be expected that the cercaria will develop in a bivalve. The only bivalves found in the River Murray itself (that is, not including its adjacent swamps) are *Velesunio ambiguus* (Philippi), *Alathyria jacksoni* Iredale and *Corbiculina angasi* Prime. Large numbers of these have been isolated since 1937, but the only cercariae observed have been *Cercaria trichofurcata* and *C. velesunionis* Angel, 1961, a gasterostome. Cable (1954) referred to the many fellodistomatid cercariae in which the tail was reduced or even absent, and stated that these were examples of caudal reduction associated with the abbreviation of free-swimming activity. In the same paper he described *Cercaria laevicardii* which developed in the marine lamellibranch, *Laevicardium mortoni*. Although 25–33% of these clams were infected, no cercariae emerged spontaneously from over 200 of them isolated for 48 h. When the clams were opened, many actively swimming cercariae escaped. It is possible that the cercaria of *Tandanicola bancrofti* does not escape from its host: this could be because it is tail-less or nearly so, or because its pattern of behaviour is similar to that of *Cercaria laevicardii*.

Sporocyst

In the original description of *C. trichofurcata* the sporocyst was described as branching. Since that time I have been able to examine living sporocysts on a number of occasions, and it is clear that there is no branching. Mature sporocysts sometimes have a beaded appearance, with narrow waists between the areas containing cercariae. In the molluscan tissues the sporocysts become entangled at these narrow parts, and after fixation they may appear to be branched.

DESCRIPTION. Sporocysts unbranched. Longer ones about 3·5 mm × 0·35 mm. Width uniform when full of cercariae, beaded when some of cercariae discharged. In latter form, may be a narrow terminal tip, up to 0·92 mm long × 0·085 mm wide. No excretory tubules seen, but flame cells clear; 40 flame cells seen in field of 130 μm radius. Larger sporocysts contain 10–12 fully formed cercariae.

Cercaria

Since the occurrences reported in 1940, *C. trichofurcata* has been found in 39 of 7044 *Corbiculina angasi* collected from the River Murray between Tailem Bend and Swan Reach. (Thirty seven of these infections were from Tailem Bend, and one each from Swan Reach and Bow Hill.)

In March, 1957 four *C. angasi* infected with *Cercaria trichofurcata* were collected from Tailem Bend. Because the cercariae from two of these hosts appeared macroscopically smaller than those from the other two, the cercariae were measured after having been fixed under the same conditions (i.e. in hot formalin). Measurements of cercariae (average of ten) from the four hosts are: 309 × 233, 307 × 235, 423 × 294, 435 × 282. (In 1940, we reported the average measurements of cercariae fixed in formalin as 314 × 184.) Although the cercariae from the four hosts mentioned above were examined closely, no differences other than the size were detected.

It is of interest that the anlagen of the reproductive system in the cercaria were correctly interpreted in 1940, with the exception that the knot of cells described as 'the future cirrus sac' probably represents the genital atrium.

The only character which appears to have changed, although only slightly, from cercaria to adult is the sucker ratio. In 1940, we recorded the ratio of oral to ventral suckers as 6:7. In twenty cercariae measured (living) since then, the ratio was 1:1·05, and in ten young adults obtained experimentally (living), the ratio was 1:1. As now recorded, the ratio in the adult varies from 1:0·8 to 1:1.

Young adult

The specimens obtained after exposure of young catfish to *C. trichofurcata* could have been up to 14 days old. None was mature. The reproductive anlagen had increased only a little in size, and vitellaria and eggs were not yet formed.

Six specimens fixed in hot formalin measured from 247 × 109 to 367 × 125 (average 321 × 119). Six specimens fixed in the same way after intravitam staining with orange G, and mounted in Canada balsam, measured 341 × 153 to 432 × 164 (average 380 × 179). The width of the oral sucker was 96 and of the ventral, 91 (averages).

Other trematodes recorded from *Tandanus tandanus* are *Anchylodiscus tandani* Johnston & Tiegs, 1922, *Isoparorchis tandani* Johnston, 1927 and *Tandanicola bancrofti* Johnston, 1927.

FROM ANGEL, 1971

Fellodistomum fellis (Olsson,1868) Nicoll,1900

Final host: Anarhichas lupus
Anarhichas minor

Location: gall bladder

Molluscan host: Nucula tenuis , a lamellibranch

2nd intermediate host: Ophinra sarsi , a brittle star

Ophiura albida, acc Mortensen (1924,1927)

References: Tauson, A. (1917) Adolescaria ophiurae, a parasite of Ophirua sarsi Lutk. (In Russian) Zool.vestn. 2.

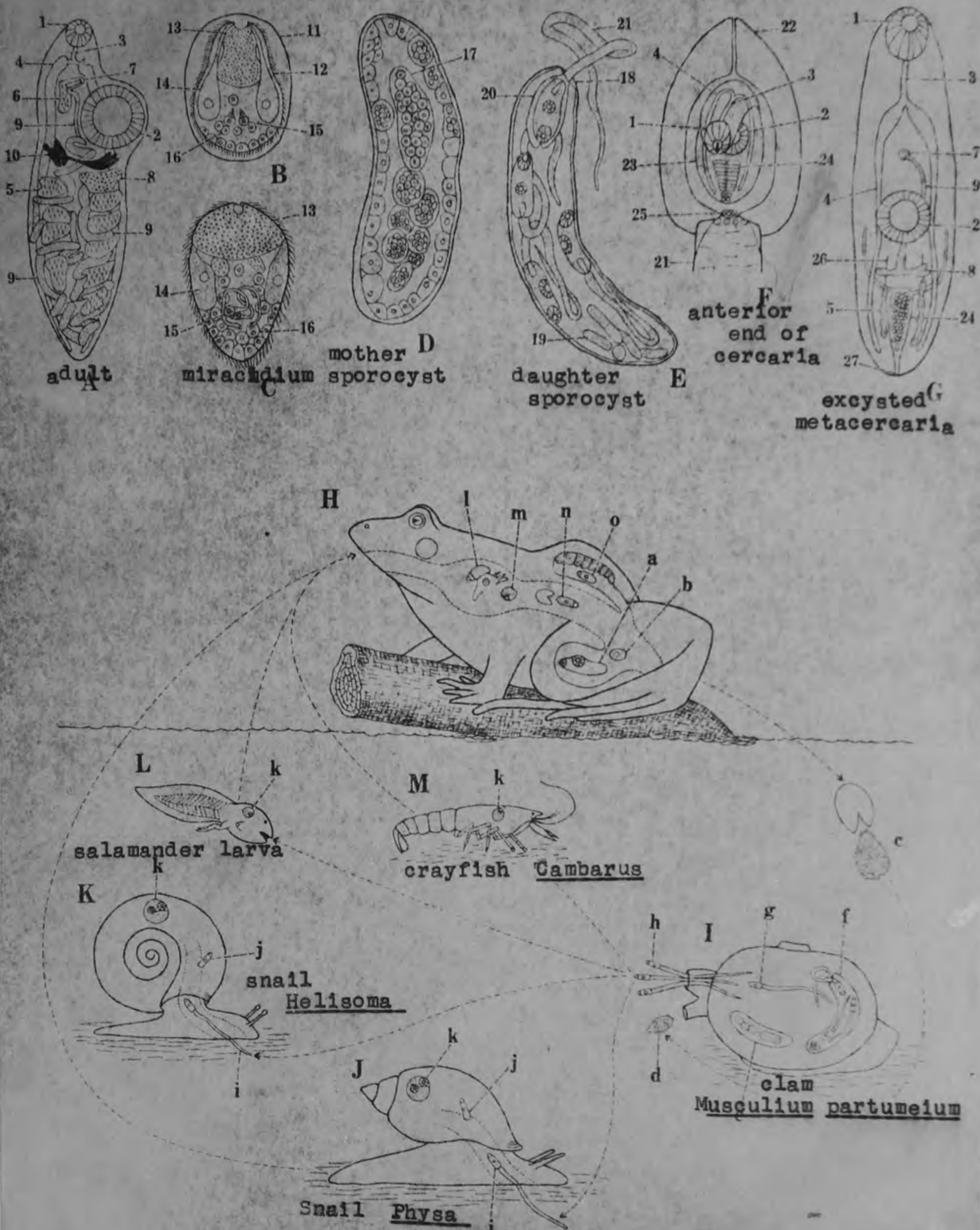
Chubrik,J.K. 1952. Larval stages of Fellodistomum fellis Nicoll 1903 from invertebrates in the Barents Sea (In Russian) Zoologitcheskij Zurnal 31.

Mortensen, T. 1924: Pighude/ Danmarks Fauna Kobenhavn.
1927. Handbook of the echinoderms of the British Isles. Oxford Univ. Press.

Brinkman, Aug. 7. 1956

FELLODISTOMIDAE

PLATE 50 *Gorgodera amplicava* from Olsen after Goodchild, 1948 J.Parasit.34:407



Gorgoderina attenuata (Stafford, 1902) Stafford, 1905

LIFE CYCLE OF GORGODERINA ATTENUATA

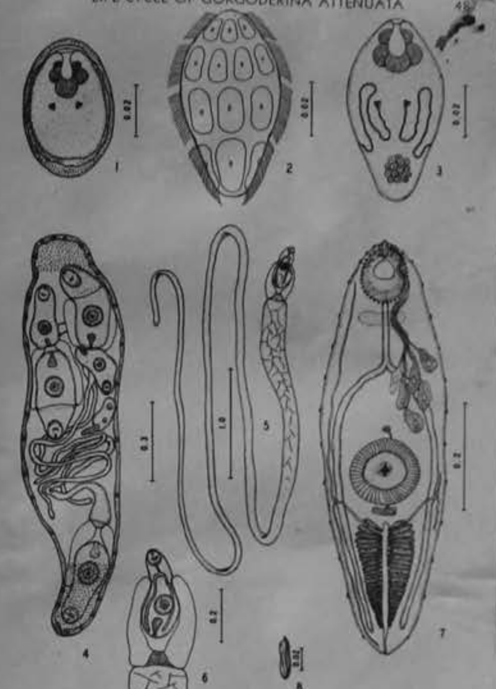


PLATE 1: Fig. 1. Egg with ripe miracidium, showing flame cells and glands around gut; Fig. 2. Miracidium with epithelial plates and cilia; Fig. 3. Miracidium showing excretory system and genital primordia; Fig. 4. Daughter sporocyst with developing cercariae; Fig. 5. Cercaria, entire specimen; Fig. 6. Enlargement of head chamber with body of cercaria; Fig. 7. Enlargement of body of cercaria to show body details; Fig. 8. Stylet.

From Rankin, H. S. 1939
Am. Midl. Nat. 21: 476-487

The Life History of *Gorgodera australiensis* Johnston, 1912

Gorgodera australiensis is a trematode parasite which commonly occurs in the urinary bladder of frogs. Because of its ubiquity, its typical trematode life history, and the comparative ease with which its intermediate hosts can be obtained and infected, it is a good subject for class study. It does not require much planning to ensure that live material of all stages of the life history is simultaneously available to students.

The adult of *Gorgodera australiensis* was first described by Johnston (1912), from Australian frogs. McFarlane and Northern (1953) described it from New Zealand frogs, and gave some notes on the collection and preparation of the trematode. For convenience of reference, a figure is given here, and some further information added. Most of the details of the body structure can be observed by flattening the live fluke under a coverslip, when the functioning excretory and reproductive systems can be watched under high power. Fixed specimens stained with Delafield's haematoxylin show good definition of the reproductive ducts. Several *Gorgodera* adults of various ages may be found in each frog bladder, and the most useful specimens are the smaller, pale worms. The larger, elderly yellow flukes are often so packed with mature egg capsules that little else can be seen.

Adult

The testes are prominent, and are arranged in two series of five and four. They are connected longitudinally by two vasa deferentia which unite near the anterior margin of the acetabulum and pass into the large vesicula seminalis. The latter curves about the genital atrium and passes into the cirrus. The vasa defferentia may contain sluggishly moving sperm, and are particularly prominent in younger individuals.

The ovary is compact, with smooth lobes, and has a central clear patch of formed ova which marks the beginning of the oviduct. This ducts begins as a narrow tube running slightly to one side, then widens into a fertilisation space which is frequently full of active sperms drawn up by the strong contractions of the oviduct. Occasionally, one or more ova may be seen in the duct, surrounded by frenzied sperm. Laurer's canal is a narrow tube opening just behind the vitelline lobe. It is contractile, and may contain a few sperms.

The vitelline glands are lobed structures posterior to the acetabulum, joined by transverse ducts to a median vitelline reservoir, and this in turn opens to the ootype. Vitelline cells may be seen in the ducts. The ducts and reservoir are contractile, and groups of cells are forced backwards and forwards until a few drop into the ootype. Mehlis' gland surrounds this chamber at the junction of vitelline duct and oviduct. It is a rounded clump of elongate cells usually showing in the space between and just anterior to the vitelline glands, and obscures further observation of the ducts at this point. When the duct becomes visible again, the first stage of egg shell development is apparent as a delicate elastic membrane surrounding the ovum and vitelline material. The shell is still soft, and may bend double in a turn of the uterus. Further down, the older shells are firm, and the vitelline cells eventually disappear.

The coils of the uterus extend through the posterior part of the body, forming loops between the testes, and between the testes and the edge of the body. The ascending coil makes several transverse turns in the region of the ovary and runs forward to the genital atrium. In old specimens these coils may obscure the ovary and vitelline area. The oldest capsules in the distal part of the uterus contain fully developed mobile miracidia.

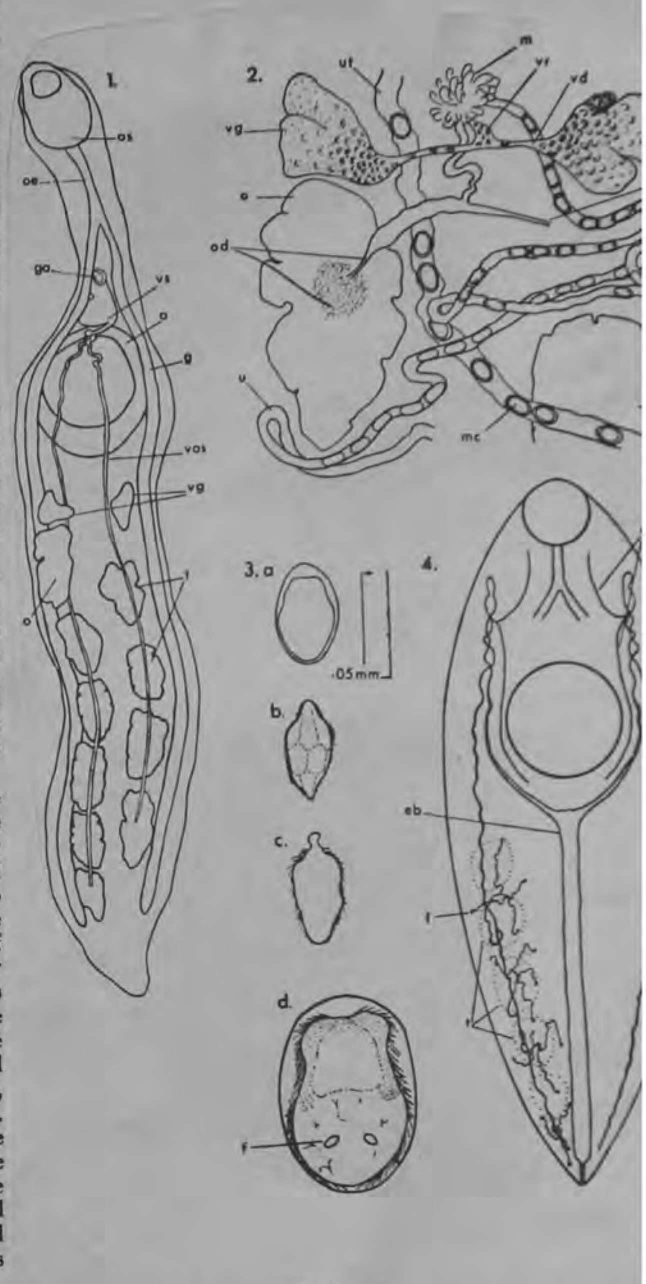


PLATE 1:

FIG. 1: Adult. FIG. 2: Ovary and associated structures. FIG. 3: Miracidi showing attitudes, a: in capsule, b: swimming, c: exploring, d: detail in caps FIG. 4: Plan of main adult excretory ducts. Detail of accessory tubules sh on left in testes region to indicate type of branching.

Abbreviations: a, actabulum; ac, anterior collecting tubule; eb, excretory blad f, flame cell; g, gut; ga, genital atrium; L, Laurer's canal; m, Mehlis' gl mc, capsules with miracidia; o, ovary; od, oviduct; oe, oesophagus; os, oral suc ov, oviduct; pc, posterior collecting tubule; t, testis; u, uterus; ut, coil of ut ascending to atrium; vas, vas deferens; vd, vitelline duct; vg, vitelline gland; vitelline reservoir; vs, vesicula seminalis.

over

A median longitudinal excretory bladder extends from a point just behind the oviduct to an opening at the posterior tip of the body. At the anterior end it is joined by two large collecting tubules which run forward to about the level of bifurcation of the gut. The ducts are extremely convoluted and difficult to follow at this point, but appear to reflex and run posteriorly for a short distance before dividing into a large posterior branch and a smaller anterior branch on each side. This agrees with the diagnosis for the genus given by Byrd, Venard and Reiber (1940). The anterior collecting tubule has a number of flame systems in the area from the base of the acetabulum forward, and the posterior branch seems to have four systems, each with possibly four or six flame cells. Byrd, Venard and Reiber give a pattern of $2 \times 8 \times 4 = 64$ flame cells for the material they studied.

FROM DALE, 1967

Gorgodera australiensis Johnston, 1912

from: Dale, 1967 (See reprint)

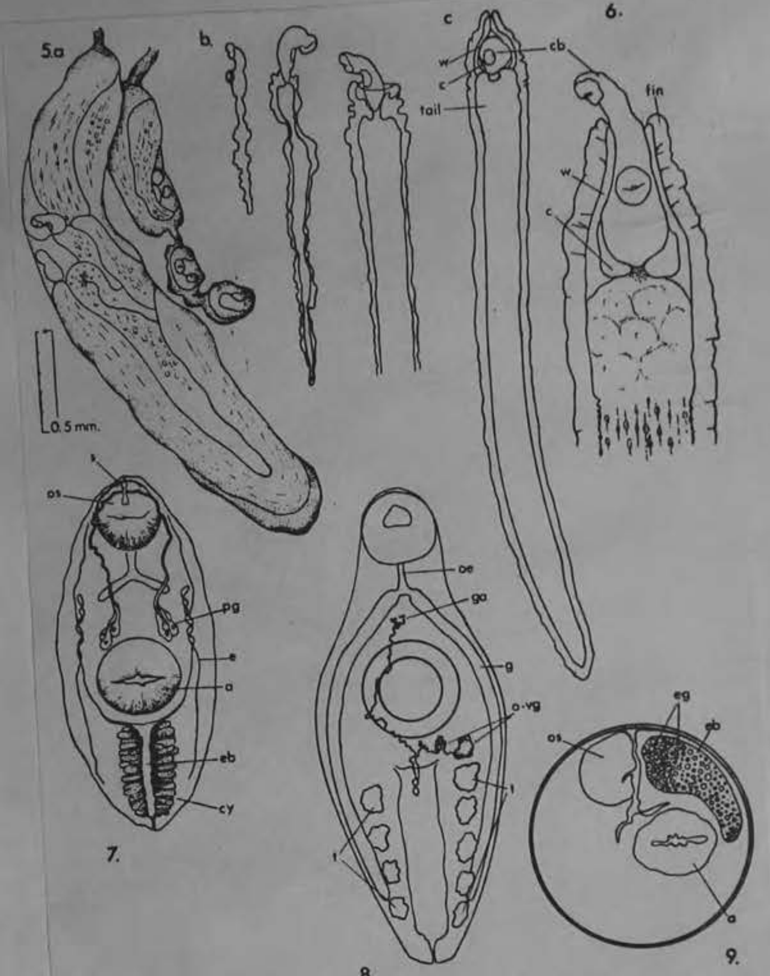


PLATE II:
FIG. 5: (to same scale) a: two sporocysts, one mature, one old; b: stages of cercaria development found in sporocyst; c: swimming cercaria. FIG. 6: Detail of cercarial chamber. FIG. 7: Cercaria. FIG. 8: Metacercaria. FIG. 9: Metacercaria in cyst.
Abbreviations: c, chamber; cb, cercarial body; cy, cystogenous cells; e, excretory tubules; eg, excretory globules; pg, penetration glands; s, stylet; w, wall of chambers. Others as in Plate I.

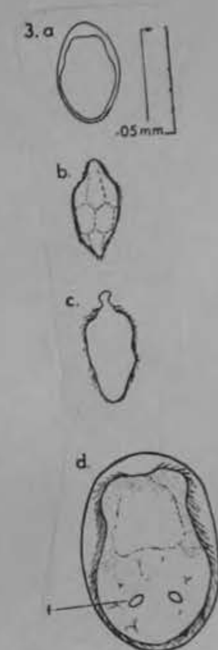


FIG. 3: Miracidium
a: in capsule, b: swimming, c: exploring, d: detail in capsule

Life Cycle of *Phyllodistomum bufonis* (Digenea: Gorgoderidae) from the Boreal Toad, *Bufo boreas*

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ABSTRACT: The life cycle of *Phyllodistomum bufonis* is described and illustrated. Hosts include fingernail clams (*Pisidium adamsi*), naiads of dragonflies (*Libidula* sp.), and toads (*Bufo b. boreas*). Experimental infections performed by feeding progenetic metacercariae to various amphibians and fish indicated that only *B. boreas* could serve as the definitive host. The formation of testes from nine primordia appears to characterize the genus *Gorgoderina* whereas the development of the testes from a single primordium is distinctive of *Phyllodistomum*.

The validity of the trematode genera *Gorgo-lerina* Looss, 1902, and *Phyllodistomum* Braun, 1899, has been questioned by various authors ince Osborn (1903) described a transitional pecies, *P. americanum*, from *Ambystoma tigri-ium* in North America and noted its similarity o *G. translucida* Stafford, 1902, from *Bufo lentiginosus* and *Rana virescens* (probably *B. americanus* and *R. pipiens*). Goodchild (1943) listed the various authors who have commented on the identity of these trematode genera.

Crawford (1939, 1940) published brief accounts of the life cycle of *P. americanum* based on specimens collected in Colorado from the boreal toad, *B. boreas* Baird and Girard, 1852, and the tiger salamander, *A. tigrinum* (Green, 1825). Adult flukes passed eggs containing miracidia which upon hatching penetrated *Pisidium* sp. Cystocercous cercariae, shed by the bivalve, encysted in the esophagus when eaten by trichopteran larvae, diving beetles, or by naiads of damselflies. Juvenile flukes in *Bufo* migrated first to the kidneys where they remained for 2 weeks before proceeding to the urinary bladder where they matured in approximately 5 weeks.

Frandsen (1957) described *P. bufonis* from *B. boreas* in Utah and distinguished this species from *P. americanus* "by its different sucker-size ratio, the significantly smaller size of its capsules, and by the fact that *P. americanum* has a slight posterior notch." Tonn (1950, 1961) found morphological variation in *P. bufonis* from *B. boreas* in Colorado sufficiently great to nclude all species described for the genus.

Since Crawford (loc. cit.) did not publish detailed observations on the material that he studied and may have confused two species, he present study was undertaken to determine he morphology of the larval states and the specific identity of the *Phyllodistomum* from *B. boreas* in Colorado.

Materials and Methods

Mature *Phyllodistomum* were obtained from *Bufo boreas* collected at Trapp Lake, Larimer Co., Colorado. Fingernail clams, *Pisidium adamsi* Prime, collected at the same locality, shed cercariae of the *Phyllodistomum* sp. in he toad.

Parasite-free clams were raised in stender dishes at room temperature for several weeks before being exposed to miracidia. Monomiracidial races of *Phyllodistomum* were established and development of the larval stages studied. Naiads of dragonflies, *Libellula* sp., were collected from small pools lacking fish or amphibia and allowed to eat cercariae from experimentally infected clams. Metacercariae obtained by dissection of the naiads were fed by stomach tube to numerous hosts: *B. boreas* from Trapp Lake; *B. woodhousei woodhousei* Girard, 1854, from gravel pits 4 miles east of Windsor Reservoir; *Rana pipiens brachycephala* Cope, 1889,* from tree dump, north edge of Fort Collins; *Ambystoma tigrinum mavortium* Baird, 1850, from tree dump, north edge of Fort Collins; *B. woodhousei woodhousei* Girard, 1854, from gravel pits 4 miles east of Windsor Reservoir; and a topminnow, *Fundulus sciadicus* Cope, 1865, from the tree dump. *B. woodhousei*, *Bufo boreas*, and *F. sciadicus* were reared from eggs or fry and maintained free of trematodes. Other amphibians were examined in the laboratory for helminths before being used in experiments.

Adult trematodes were killed in warm AFA, stained in Grenacher's alum carmine, cleared in beechwood creosote, and mounted in Piccolyte before measuring. Measurements are based on five specimens from each of 10 toads. All measurements are in millimeters unless otherwise indicated. Drawings were made with the aid of a camera lucida, microprojector, and by tracing projected photomicrographs.

Results

Egg and miracidia (Figs. 1, 2)

Eggs freshly deposited, 24.0 to 35.3 μ long by 18.4 to 23.1 μ wide, ovoid, nonoperculated, increasing in size while *in utero* to accommodate developing miracidia; eggs in metraterm often with dark shell and resistant to immediate hatching in water.

Miracidia fully developed in eggs when laid. Hatching occurs within minutes after eggs are placed in water. Body mucrocuneate in shape, often assumes pyriform shape when swimming, 0.053–0.067 long by 0.030–0.042 wide. Fifteen ciliated epidermal plates present, arranged in three transverse rows with six plates in each of the first two rows and three in the last row. Apical gland in anterior region of body, 0.012 to 0.010 long by 0.029 to 0.021 wide, opens in a small apical pore. Large asymmetrical gland of Goodchild (1943) opens in space at anterior end of body; smaller homologue gland of Goodchild present in miracidia younger than 12 hr, opens similar to asymmetrical gland. Two flame cells present near middle of body, ducts open on lateral margins just anterior to last row of epidermal plates. Four germ cells present in encapsulated miracidia.

Wootton and Peters (1957) listed 15 epidermal plates for miracidia of *Gorgoderina attenuata*, *P. superbum*, *P. staffordi*, and *P. undulans*, all parasites of fishes as adults except *G. attenuata*. Goodchild (1943) reported that 16 plates were present on miracidia of *P. solidum* (over)

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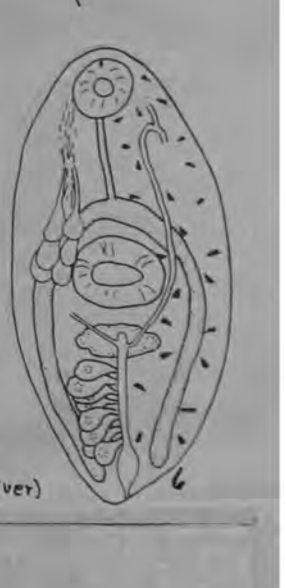

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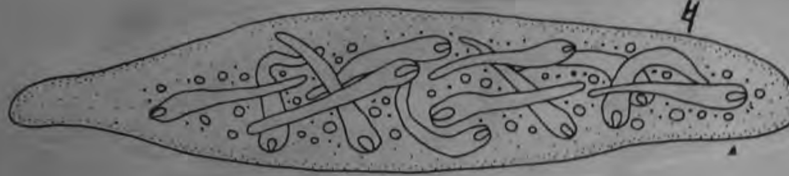

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and Schell (1967) found 18 plates on *P. staffordi*. The morphology of miracidia of *P bufonis* are similar to those of other gorgoderids having a 6, 6, 3 pattern of epidermal plates.

Mother sporocyst (Fig. 3)

Development of the mother sporocyst occurs within the gill lamella of *Pisidium adamsi* as described by Goodchild (1943) for *P. solidum* and Schell (1957) for *P. staffordi*. After 36 hr, the central cavity can be differentiated from the wall of the sporocyst and by 70 hr the cells with granular cytoplasm appear (Fig. 3). Embryos of daughter sporocysts are present as early as 80 hr after infection. Sixteen days after infection, the sporocyst moves to the inner surfaces of the gill lamellae. Twenty-one days after infection, mother sporocysts 0.45 long split, releasing the daughter sporocysts.

Daughter sporocysts (Fig. 4)

Daughter sporocysts are located in the gills anchored by the end with the birth pore with the opposite end extending into the interlamellar gill space. Sporocyst body tubular, 1.00 to 1.96 long by 0.55 to 0.70 wide; sporocyst wall generally wrinkled, thinner than wall of mother sporocyst, and contains similar granules. Birth pore subterminal on anterior end. Body cavity with 10 to 12 developing cercariae. Cercariae shed 38 to 48 days after initial exposure to miracidia.

Cercariae (Figs. 5–7)

Cercariae of *P. bufonis* are macrocercous, tail 1.46 to 1.93 by 0.14 to 0.19; cercarial chamber 0.14 to 0.16 by 0.11 to 0.13, neck 0.01 to 0.04 in length; anterior portion of tail as wide as chamber, diminishes gradually in width posteriorly, ending bluntly.

Body of cercaria fusiform, emerges readily from chamber under slight pressure, 0.21 to 0.25 by 0.09 to 0.11. Cuticle with fine striations and grooves. Stylet robust, 0.018 to 0.025 by 0.003 to 0.004. Oral sucker 0.040 to 0.055 by 0.054 to 0.060; acetabulum 0.041 to 0.070 by 0.062 to 0.082. Twelve unicellular penetration glands present, six per side, located dorsolateral to acetabulum, open in two pores on each side of stylet. Esophagus bifurcates just anterior to acetabulum into ceca which extend to posterior margin of the body. Excretory pore terminal; bladder extends to posterior margin of acetabulum, receives two main collecting ducts anteriad (subterminally), ducts extend to near posterior border of oral sucker before dividing. Flame cell pattern $2[(4+4)+(4+4+4+4)]=48$; bladder surrounded by cystogenous cells. Genital primordium immediately posterior to acetabulum and ventral to the anterior end of excretory bladder, 0.008 to 0.012 by 0.03 to 0.04.

Remarks

Cercariae of *P. bufonis* leave via the birth pore after rupturing the thin host membrane surrounding the sporocyst are free in the interlamellar space and epibranchial cavity eventually to emerge through the excurrent siphon during day or night. The cercariae and sporocysts appear to do little physical damage to the host. Sporocysts, however, inhibit reproduction. Infected clams from experimental or natural infections never contained young clams.

The cercaria resembles other gorgoderid cercariae that are macrocercous, possess stylets, and have 12 penetration glands. The wide anterior portion of the tail is similar to *Cercaria conica* Goodchild, 1939; however, the remainder of the tail is not set off as distinctly and the stylet shape is different.

Metacercaria (Fig. 8)

Macrocercous cercariae liberated from the clam adhere to the substratum where they contract and extend vigorously for several hours. Naiads of dragonflies, *Libellula* spp., readily ate the cercariae which penetrated the intestinal wall and encysted in the hemocoel by means of secretions from the cystogenous glands as described by Sinitsin (1905), Goodchild (1943), and Thomas (1958). Metacercariae were usually found in the hemocoel near the posterior end of the body. Two-day-old metacercariae measure 0.16 to 0.20 in diameter. Older ones are slightly larger. Genital organs are differentiated. In the oldest metacercariae eggs are already present in the uterus.

Table 1. Results of feeding amphibians and fish with 10 metacercariae of *Phyllodistomum bufonis*.

Hosts	No. specimens	Percentage infected after 48 hr
Ambystoma tigrinum uthaense	5	0
Ambystoma tigrinum mavortium	11	0
Rana pipiens (northern variety)	6	0
Bufo woodhousei	18	0
Bufo boreas	34	97
Fundulus sciaticus	6	0

This is the first report of a progenetic *Phyllodistomum* from the United States. Rai (1964) reported progenetic metacercariae of *P. srivastiava* occurred in *Macrobrachium dayanus*, a freshwater shrimp in India.

Adult trematode (Figs. 9, 10)

The adult trematode used in this study resembles *P. americanum* and *P. bufonis* with minor exceptions. Measurements given by Osborn (1903) and by Frandsen (1957) reveal that *P. americanum* is smaller in size, the acetabulum is located more anteriorly, and the excretory bladder extends only to the posterior testis. Flame cell formula $2[(4+4)+(4+4+4+4)]=48$ in *P. bufonis*.

Crawford (1940) reported that both *Bufo* and *Ambystoma* were infected with *P. americanum*. Tonn (1950) noted that *Rana pipiens*, *Ambystoma* spp., and *Pseudacris triseriata* collected with *B. boreas* were never infected with *Phyllodistomum*. To determine if various amphibians and fish could serve as experimental

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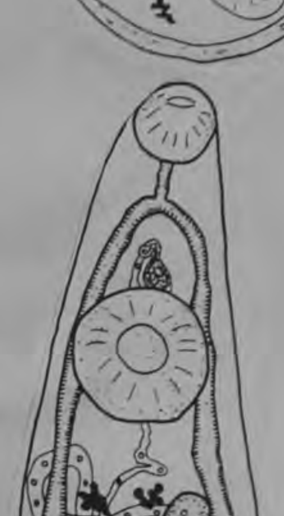

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hosts, 10 metacercariae were fed to each of several hosts (Table 1). Only *B. boreas* became infected, whereas *Ambystoma* spp., *R. pipiens*, *B. woodhousei*, and *F. sciaticus* did not.

Goodchild (1943) was unable to infect *Triturus viridesans*, *R. pipiens*, *R. palustris*, *R. catesbeiana*, *R. clamitans*, *Micropterus dolomieu*, *Eupomotis gibbosus*, *Carassius auratus*, and *Cyprinus* sp. with metacercariae of *Phyllodistomum solidum* from *Desmognathus fuscus*.

Rai (1964) reported that metacercariae of *P. srivastavai* fed to *Heteropneustus fossilis*, *Mystus cavasius*, and *Rana limnochairs* excysted only in the first host.

Several *Phyllodistomum* spp., on the other hand, are reported to have many definitive hosts. Dawes (1956) believed that many of the species will become synonyms of *P. folium* when additional knowledge is gained on the range, variability, and specificity of this group. Based on experimental evidence adult *P. bufonis* appear to be host-specific.

The validity of *Gorgoderina* and *Phyllodistomum* have been discussed by various authors. Dollfus (1958) discussed the systematics of the phyllodistomes and concluded that the shape of the body and the class of the host should serve to distinguish between *Gorgoderina* and *Phyllodistomum*.

The phyllodistomes have undergone evolutionary radiation in fish and the gorgoderids in amphibia. A few species of phyllodistomes are reported to occur in amphibia, including the transitional species *P. americanum* and *P. bufonis*. We believe the development of the testes to be a more reliable character, especially for transitional species, on the genetic level. In the genus *Gorgoderina*, testes form from a fusion of nine primordia or "anlagen" (Rankin, 1939). The anlagen each form distinct testes in the *Gorgoderina* but in *Phyllodistomum* only a single primordium is present (Goodchild, 1943; Rai, 1964). We can find no exception to this characteristic and propose its use particularly when other characters are in doubt. *P. bufonis* shows formation of testes from a single anlagen and is properly placed in the correct genus. We cannot agree with Pande (1937), Kaw (1950), or Frandsen (1957) who consider *Gorgoderina* to be a synonym of *Phyllodistomum* until species assigned to *Gorgoderina* are examined more critically and life cycles are elucidated.

Goodchild (1943) suggested that *G. schistorchis* Steelman, 1938, and *G. tenua* Rankin, 1937, should be included in the genus *Phyllodistomum* since they possess prominent uterine coils between the vitelline complex and the acetabulum. Since *P. bufonis* does possess prominent uterine coils between the vitelline complex and the acetabulum which are more highly developed in older and larger worms but has testes developing in a phyllodistome fashion, we consider *G. tenua* and *G. schistorchis* as belonging to the genus *Gorgoderina* until additional information is available concerning testicular development.

Crawford (1939, 1940) reported that *P americanum* was present in both salamanders and toads and that miracidia were obtained from flukes in these two hosts for life cycle studies; however, our failure to infect salamanders with metacercariae, presumably *P. americanum*, originating from toads indicates that perhaps Crawford was dealing with two species of flukes, the species in toads being *P. bufonis*, the species in salamanders being *P. americanum*. Since it is not known experimentally whether *P. americanum* can infect toads, no definite conclusions may be drawn concerning the exact identity of Crawford's material.

In the same manner, the experimental work presented herein does substantiate Frandsen's decision to name those flukes from *B. boreas* as a distinct species.

From Ubelaker and Olsen, 1972

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STUDIES ON HELMINTHS OF NORTH DAKOTA. V. LIFE HISTORY OF *PHYLLODISTOMUM NOCOMIS* FISCHTHAL, 1942 (TREMATODA: GORGODERIDAE)*

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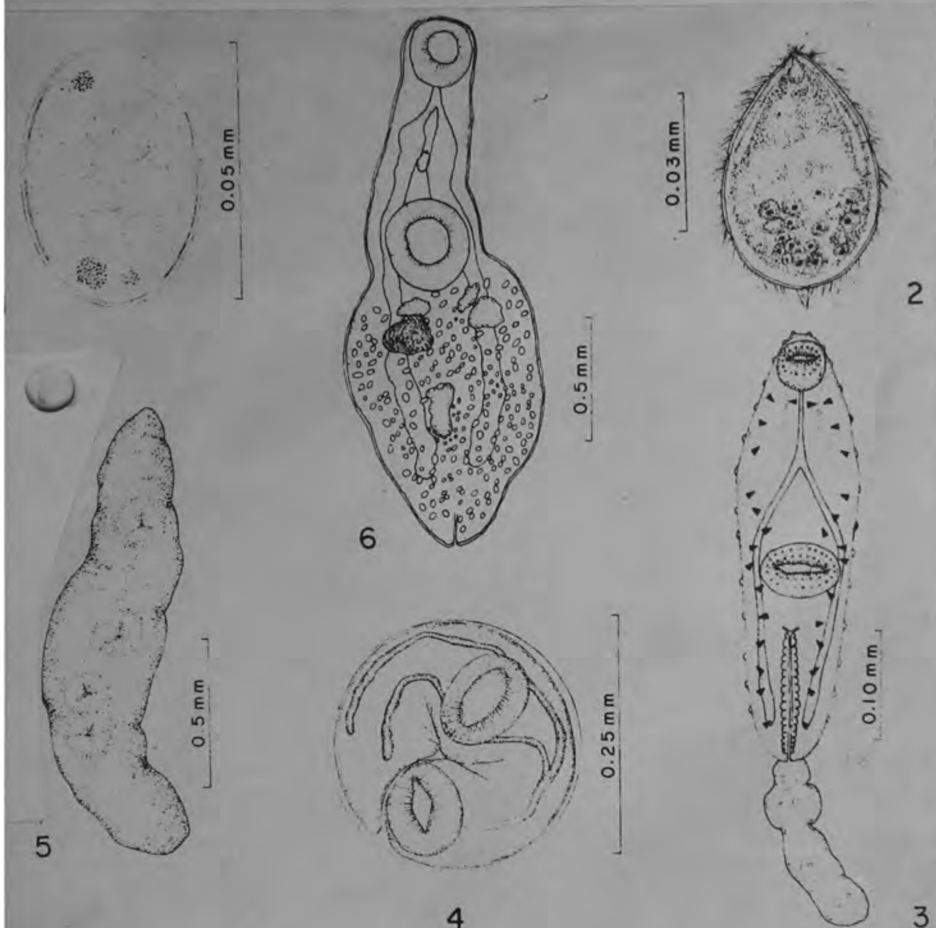
ABSTRACT: Sporocysts and cercariae develop inside the gills of the fingernail clam, *Sphaerium striatinum*, and cercariae encyst within their daughter sporocysts. Metacercariae fed to 4 species of minnows were recovered as immature worms from kidney ducts and urinary bladders of all 4 species. Only in hornyhead chubs (*Hybopsis biguttata*) did worms mature into egg-bearing adults. This definitive host acquires the parasite by eating infected clams.



FIGURES 1–6. Stages in development of *Phyllodistomum nocomis*. 1. Egg from distal portion of uterus. 2. Miracidium. 3. Cercaria. 4. Encysted metacercaria. 5. Daughter sporocyst possessing four metacercariae. 6. Adult from a natural infection of *Hybopsis biguttata*.

Egg and miracidium (Figs. 1–2)

Fully developed eggs elliptical, colorless, transparent, and nonoperculate. Eggs in proximal region of uterus average 24 by 17; those in distal portion 70 by 46. Embryonated eggs hatch within 2 min in distilled water. Miracidia 61 to 71 long, 41 to 51 wide, pear-shaped, with 2 penetration glands lateral to mid-region and 10 to 20 germinal cells in posterior half.

Daughter sporocyst (Fig. 5)

Fully developed living daughter sporocyst white, tubular, immobile, 1.8 to 2.2 mm long, 0. to 0.6 mm wide, and contain 2 to 11 cercaria and/or metacercariae. Sporocysts enveloped by 1-cell-thick epithelial lining of host gill origin similar to that surrounding clam embryos.

Cercaria (Fig. 3)

Cercarial body 501 to 229 long, 143 to 15 wide, tegument with numerous small papillae. Oral sucker subterminal, nearly circular, diamete 72 to 85. Ventral sucker width 86 to 102. Mout leads directly into narrow esophagus, esophagu bifurcates midway between suckers. Well-de veloped stylet lacking, but refractile fragme evident in some which may be a vestigial styl Four pairs of ducts run posteriorly from anter end, but penetration glands not discerned. At le 15 flame cells on each side of body. Tail i mobile, heavy, 143 to 229 long, 70 to 72 wi with proximal portion slightly bulbous and e blunt. Parenchymatous cells scattered through tail.

Metacercaria (Fig. 4)

Metacercarial cysts spherical, transparent, av age 257 in diameter. Morphology of worm sentially that of cercaria without tail. Metacer cariae from decomposing clams showed norma movements even if sporocyst tissues were necrotic

Adult (Fig. 6)

Measurements of 10 mounted specimens from naturally infected hornyhead chubs: length 1.6 mm to 2.65 mm; maximum width 0.50 mm t 1.02 mm. Oral sucker diameter 186 to 243; ven tral sucker width 301 to 349. Average ovary siz 187 by 150. Amphitypy apparently common: specimens with ovary on left, 6 with it on right.

These specimens agreed with the original de scription of the species in all diagnostic featur except body size, uterine characteristics, and eg size. Body size is nearly twice that described fo type specimens, the uterus is extensive with nu merous eggs rather than sparse with few egg and the eggs are larger.

GORGODERIDAE