SOME PARASITIC WORMS IN FRESHWATER FISHES AND FISH-PREDATORS FROM THE TRANSVAAL, SOUTH AFRICA.

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ABSTRACT

This report concerns a collection of parasitic worms from South Africa, and contains a new species of monogenean, *Gyrodactylus transvaalensis*, six species of adult trematodes, including a new species of *Phyllodistomum*, *P. van der waali*, two metacercariae of the Family Clinostomidae and three of the Order Strigeida, as well as two species of cestodes, and larvae of the nematode genus *Contracaecum*. The adults of previously-known helminths are redescribed, with some remarks on their systematics and biology. Accompanying the material of the new gyrodactylid monogenean there is a specimen which is thought to be a giant of the new form, and this appears to be the first recorded suggestion of the occurrence of gigantism in the Monogenea, and in fact in any kind of helminth.

INTRODUCTION

The following is a list of determinations, with descriptions of one new monogenean and one new trematode, and some redescriptions and morphological notes on other worms, including a larval cestode and some larval nematodes. This material will be incorporated into the helminthological collections of the British Museum (Natural History).

The helminths infesting fishes in the Transvaal appear to have been the subject of only four short papers, one by Ortlepp (1935), one by Price *et al.* (1969) and two by Lombard (1960, 1968). It is, therefore, not surprising that most of the following records are new to this area of southern Africa.

Unfortunately, relatively little is known of the helminths of freshwater fishes in southern Africa, and in view of the fact that the few known digenetic trematodes from these hosts show, on the one hand, a close resemblance to forms occurring in South American fishes, and on the other hand to forms in freshwater fishes of the Indo-Malaysian region, it would appear that more studies on the parasitic worms from African freshwater fishes and amphibians might produce more evidence of their ancient zoogeography, particularly in relation to continental drift.

MATERIALS AND METHODS

The material described in this paper was obtained by Mr B. C. W. van der Waal from fishes and their predators at various times during 1969–70 in the confluence of the Elands and

Olifants Rivers, about 17 km north of Marble Hall in the central Transvaal. The specimens were kindly entrusted to the senior writer for study and determination, and for this our thanks are due to Mr van der Waal.

The method for the fixation of the specimens is not known to the writers, but they were preserved in 10 per cent formalin or in 70 per cent alcohol, and stained as whole mounts with Mayer's paracarmine, or serially sectioned and stained with Ehrlich's haematoxylin and counterstained with eosin.

TAXONOMY

MONOGENEA

Family **Gyrodactylidae**

Gyrodactylus transvaalensis n.sp.

(Figure 1 a–b)

A number of specimens of this worm were found attached to the skin, particularly around the lower lip, of one-month-old fry of *Clarias gariepinus* kept in a breeding pond at the Low Veld Fisheries Research Station, Marble Hall, in December 1970.

The body, excluding the posterior adhesive organ, is more or less fusiform and measures between 0,21 and 0,29 mm in length and between 0,075 and 0,085 mm in maximum width. The posterior adhesive organ or opisthaptor is discoid or somewhat obovate in outline and distinctly marked off from the body, to which it is posteriorly or ventro-posteriorly disposed. It measures 0,045–0,062 mm in length and 0,042–0,062 mm in width, and is provided with a pair of large hooks or anchors and 16 marginal hooklets. The length of the curved anchor is, without its root, 45–55 μm, whilst that of the root is 15–20 μm. The length of the anchor-shaft (*sensu* Malmberg 1970) is 25–30 μm and the length of the anchor point 20–25 μm. The transverse dorsal bar is narrow and somewhat arcuate, measuring about 12 μm in length. The transverse ventral bar is about 15 μm long, twice as thick as the dorsal bar, with obtuse ends and with both the front and hind leading edges straight. Neither membrane nor serration to the ventral bar has been made out. The marginal hooklets, of which there are 16, each measure about 25 μm in total length, of which the sickle-shaped terminal structure measures 5 μm long, whilst the sickle-filament loop is about half as long as the handle of the hooklet.

As is usual in the genus *Gyrodactylus*, the anterior end of the body has paired lobes through which open the ducts of two groups of glands lying one behind the other on either side of the pharynx. The latter organ has eight long pharyngeal processes, and its posterior segment measures 32–37 μm in transverse diameter. It opens into an oesophagus that bifurcates immediately to form a pair of intestinal caeca, which have rugose walls and extend posteriorly to a level about midway between the uterus and the opisthaptor. The reproductive system is typical of the genus. The genital pore is situated a little to the left of the median line and

ventrally to the intestinal bifurcation. The atrium contains a stout papilla, which is about 10 μm wide at its base, and is armed with a single row of eight small, slender, weakly-cuticularized spines; a large central spine on the cirrus-papilla has not been detected.

The uterus is represented as a large oval sac, usually occupied by one large well-developed embryo bearing a pair of anchors, similar in size to those of the parent, and 16 hooklets. The latter appear before the anchors. A second embryo at an earlier stage in development is occasionally present in the first embryo.

The excretory system could not be distinguished.

There have, so far, been about 15 species of the genus *Gyrodactylus* described from African freshwater fishes, and from those possessing a single row of spines on the cirrus the present form may be distinguished by the size and shape of its anchors. Another probable feature differentiating this new form is its apparent lack of a membrane to the transverse ventral bar of the armature of the opisthaptor.

Lombard (1968) recorded an unnamed species of *Gyrodactylus* from the fins and skin of trout and large-mouthed bass in the Transvaal, but gave no description of the parasites.

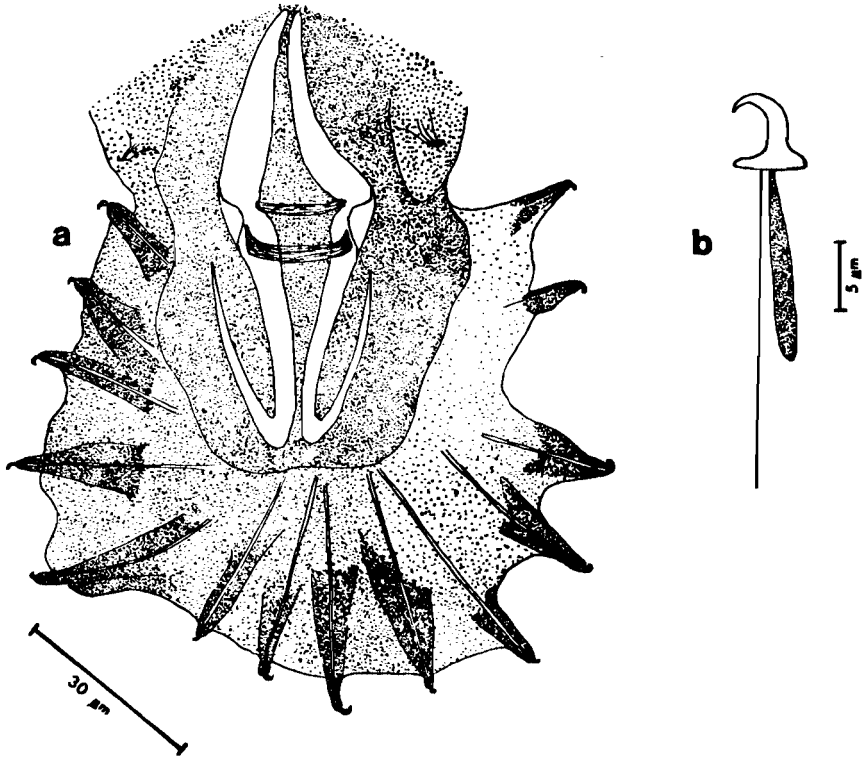


FIGURE 1

Gyrodactylus transvaalensis n.sp. (a) opisthaptor; (b) hooklet.

Gyrodactylus sp. indet.

Among the specimens of *Gyrodactylus transvaalensis* described above there was a single specimen that is morphologically identical with this species and differs only in its greater measurements. It is 0,38 mm long and 0,11 mm wide, and the diameter of its opisthaptor is similar in both length and width, 0,112 mm. Each of the two anchors on the opisthaptor measures about 110 μm in length; the anchor-shaft being about 60 μm long and the anchor-point about 50 μm long. The anchor-root is about 37 μm long. There are 16 hooklets, each of which measures 50 μm in length, but the sickle-shaped terminal structure is only 5–6 μm long. The transverse diameter of the posterior segment of the pharynx is 50 μm. The transverse ventral bar is narrow, with no membrane or serration, and is 20 μm long, whilst the dorsal bar is also narrow and 15 μm long. The uterus appears to contain a single embryo, in which anchors and hooklets are not yet developed. The excretory system was not made out.

The systematic relationship of this specimen in problematical, because it may be specifically different from *G. transvaalensis* merely on the grounds of size, or it may be a giant form of that species. The diagnostic features of the numerous known species of *Gyrodactylus* appear to be invariably found in the structure of the various cuticular elements comprising the holdfast apparatus of the opisthaptor. Apart from size, the similarity between the comparable elements in *G. transvaalensis* and the lone specimen is so great that one is inclined to the conclusion that the latter type is merely a giant example of the former. If this conclusion be accepted, it is, of course, impossible to state with certainty the physiological basis for excessive growth in this specimen, but such a phenomenon is likely to be not uncommon among monogeneans, perhaps more especially among the sanguinivorous forms.

TREMATODA

Family **Gorgoderidae**

Phyllodistomum vanderwaali n.sp.

(Figure 2)

The ensuing description is based on six mature specimens recovered from the urinary bladder of *Clarias gariepinus* from the Olifants River.

The aspinose body is small, measuring from 1,9 to 2,2 mm in length and 1,3 to 1,6 mm in maximum width, which occurs at a level just posterior to the testes. Its shape is typically ampullaceous, with a sub-cylindrical forebody amounting to about one-fifth of the total length of the body, although considered to be somewhat contracted in the present specimens; and a leaf-like, dorso-ventrally flattened hindbody, which is discoid or oval in outline. Two of the specimens, however, do not have the ampulla-shaped body, but are elongate without any significant difference in the width of the forebody and hindbody. The latter specimens measure 2,2–2,5 mm in length and 0,66–0,68 mm in maximum width.

The oral sucker is sub-terminal, and rounded. The ventral sucker is situated at about the anterior level of the hindbody, or at about the first fourth or fifth of the body-length. It is distinctly larger than the oral sucker, having a transverse diameter of 0,35 to 0,4 mm compared with a diameter of 0,23 to 0,25 mm for the latter. The measurements from individual specimens give an oral/ventral sucker ratio varying from 1:1,4 to 1,7.

As in other members of this genus, there is no pharynx. The oesophagus is short, and the alimentary canal bifurcates immediately behind the oral sucker. The intestinal caeca reach almost to the posterior end of the body.

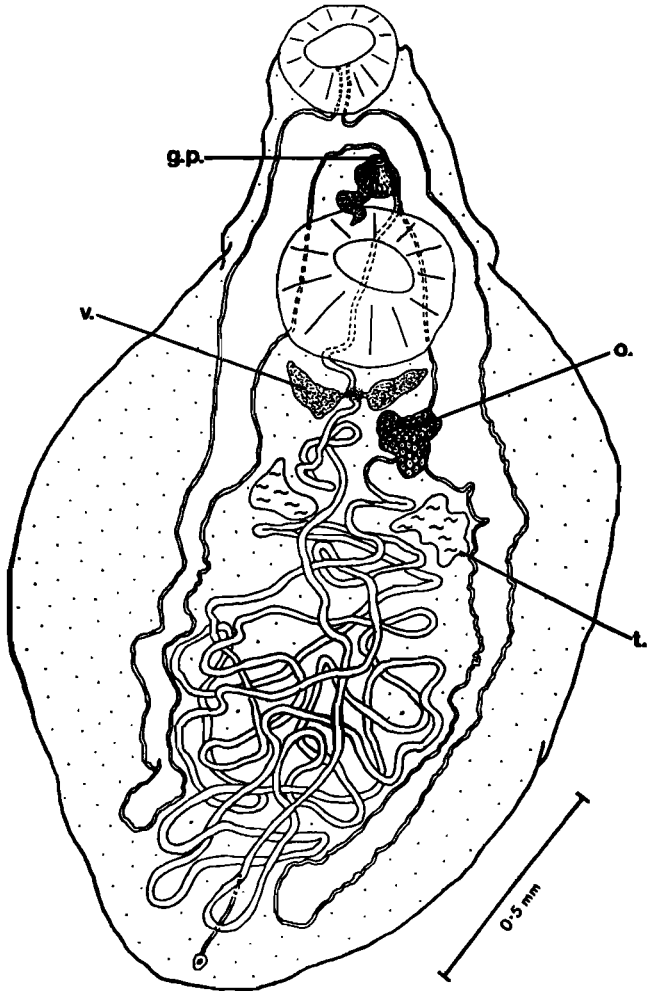


FIGURE 2

Phyllodistomum vanderwaali n.sp. (ventral view). *g.p.*, genital pore; *o.*, ovary; *t.*, testis; *v.* vitelline body.

The excretory pore opens dorsally near the hinder extremity of the body. The excretory vesicle appears as a narrow tube lying dorsally in the median line, but it has been traced anteriorly from its pore for only a short distance, where it becomes lost to view among the uterine coils.

The genital pore lies in the median line, close behind the gut-bifurcation. As is usual in the genus *Phyllodistomum*, there is no cirrus-sac, and the terminal organs of the male and female complexes lie free in the parenchyma. The ejaculatory duct is short and runs from the genital pore to open into a small pars prostatica, which is endowed with a large number of deeply-staining gland-cells. Opening into the proximal end of the pars prostatica is a distinctly convoluted seminal vesicle arising from the union of two vasa deferentia.

The two testes are situated one on either side of the median line, in the mid-region of the body. They lie between the intestinal caeca and are normally disposed symmetrically, although one testis may be slightly in advance of the other so that they appear somewhat diagonally arranged. In all the available specimens the outline of these organs is irregularly lobed or indented, but they have an amorphous appearance and their staining is diffuse. Moreover, occasionally one testis appears to be rather more degenerate than the other.

In four of the specimens the ovary lies to the right of the median line, and in the remaining two to the left, but always in front of the testes and behind the vitellaria. It measures 0,12–0,17 mm by 0,08–0,12 mm, and in outline it may assume a compact, irregularly rounded or lobed mass. The "shell"-gland complex is small and situated near the hinder margin of the ventral sucker, between the vitellaria.

The vitellaria consist of a pair of compact bodies diagonally opposed, chevron-like, between the intestinal caeca, immediately behind the posterior rim of the ventral sucker and anterior to the ovary. They are elongate, being over three times longer than broad (0,11–0,16 mm by 0,042–0,058 mm) and are thicker towards their hinder and inner ends to give the glands a conical or claviform outline.

The uterus is thrown into several convoluted folds, which fill most of the region between the intestinal caeca behind the testes. It passes anteriorly along the median line between the testes and between the vitelline bodies to reach the genital pore. The structure and position of the metraterm is not clear. The uterus contains thin-shelled eggs that measure 16–18 μm by 10–12 μm. In the distal region of the uterus there are much larger eggs (28 μm by 17 μm), each containing a miracidium. Moreover, in some of the specimens, in this region of the uterus there are free miracidia and empty egg-shells.

Five species of *Phyllodistomum* have hitherto been recorded from African fishes, three in the Sudan, namely *P. linguale* Odhner, 1902, *P. spatula* (Odhner, 1902) and *P. spatulaeforme* (Odhner, 1902), and two from West Africa, *P. ghanense* Thomas, 1958, and *P. symmetrorchis* Thomas, 1958. The present writers have been fortunate in having had the opportunity of examining specimens of all five species in the collections of the British Museum (Natural History). Of these species, the present form resembles *P. linguale* in the ratio of the suckers, but differs in the smaller size of the body, in the smaller eggs and, above all, in the constant shape and orientation of the vitelline bodies. Moreover, in the features of these bodies, the new form differs from all other species of *Phyllodistomum* hitherto described.

Members of this genus are primarily parasites in the urinary bladder of freshwater

fishes, but may occasionally be found in marine fish, as well as in amphibians. Where the life-history is known, the eggs hatch immediately on, or up to 24 hours after, entering water. The miracidium is an active swimmer that does not penetrate its intermediate host, a bivalve molluscan, from the exterior, but appears to be fortuitously carried into its host by water flowing into it through the incurrent siphon. On contact with the gills of the mollusc, the miracidium will immediately penetrate, or lodge between, the gill-filaments and transform into a sporocyst. This latter gives rise to daughter-sporocysts in which develop cercariae of the cystocercous or macrocercous type, so far not recorded from southern Africa. The cercaria escapes into water through the excurrent siphon of its host. The active cercariae are usually swallowed by predacious aquatic arthropods, in which they encyst. After the second intermediate host is eaten by a suitable fish, the metacercariae excyst in the stomach and migrate to the ureters and kidneys, where a certain amount of development takes place before the worms move to the urinary bladder to reach maturity.

Family **Acanthostomidae**

Acanthostomum productum (Odhner, 1902)

(Figure 3)

Two specimens were recovered from the intestine of a Nile crocodile (*Crocodylus niloticus*) taken in the Olifants River system. Unfortunately, these specimens are fragmentary, but sufficient of their characteristics have been made out to enable a specific determination to be made with a degree of certainty.

The parasite is elongate, sub-cylindrical in section, with a rounded posterior end. The anterior end is obtuse with a circum-oral ring of 23 spines of roughly equal size. The spines are somewhat bullet-shaped, and measure about 44 by 13 μm. The body bears very small, backwardly-pointed, narrow spines, which are clearly visible on the anterior half of the body, but which appear to be absent from the posterior half.

The oral sucker is well developed, and provided with a deep cavity. It is terminal, somewhat funnel-shaped, with a maximum diameter of 0,30 mm and a depth of 0,29 mm. The walls of the oral sucker are thick and strongly muscular, but the wall is less thick at the base of the sucker. The ventral sucker is compact and muscular, globular or pyriform, with a diameter of about 0,16 mm. It lies at about 1,16 mm from the anterior end of the body in the midline of the ventral surface. The oral/ventral sucker ratio is about 1:1,8. A prepharynx, 0,18–0,26 mm long, leads from the base of the oral sucker to a well-developed oval pharynx, measuring 0,16 by 0,10 mm. The gut bifurcates close behind the pharynx, so that the oesophagus is very short. The caeca descend beyond the posterior testis almost to the end of the body, where they open to the exterior (Figure 3b).

A genital pore is situated immediately anterior to the ventral sucker in the median line. Just anterior to the pore, and also in the median line, there is a gonotyl invested with a mass of glandular tissue just behind the intestinal bifurcation. The gonotyl is pyriform, 52 μm in

diameter and with a depth of 62 μm. Its structure would indicate that it functions as a genital sucker, and Dollfus (1950) has suggested that it may be partly eversible.

The two testes are compact, oval or rounded structures. The anterior testis measures 0,21 mm in diameter, whilst the posterior one is 0,25 mm long and 0,16 mm wide. They are contiguous and lie one directly behind the other in the posterior region of the body and between the gut-caeca. The seminal vesicle is a convoluted tube, lying just behind the ventral sucker. Its distal end joins with the distal end of the uterus to form a short hermaphroditic duct which leads to the genital pore.

The ovary is compact and rounded, 0,23 mm long and 0,17 mm wide. It lies immediately in front of, and somewhat ventrally to, the anterior testis. In one fragment it lies in the midline. The oval receptaculum seminis lies to one side of the ovary and overlaps the anterior testis.

The vitelline glands are follicular and extend as a narrow band lateral to each intestinal caecum from the anterior testis forward to about the middle level of the body. The uterus follows a sinuous course from just anterior to the ovary until it joins the hermaphroditic duct at the level of the ventral sucker. It is filled along its length with eggs measuring 33 by 17 μm. The eggs are operculate and embryonated.

There is an excretory pore at the posterior tip of the body, but further details of the excretory system have not been made out in the material available, except for a very much swollen section of the vesicle before it opens externally.

Although fragmentary, the present material has an interesting feature inasmuch as the ends of the intestinal caeca open to the exterior in the posterior region of the body. Several

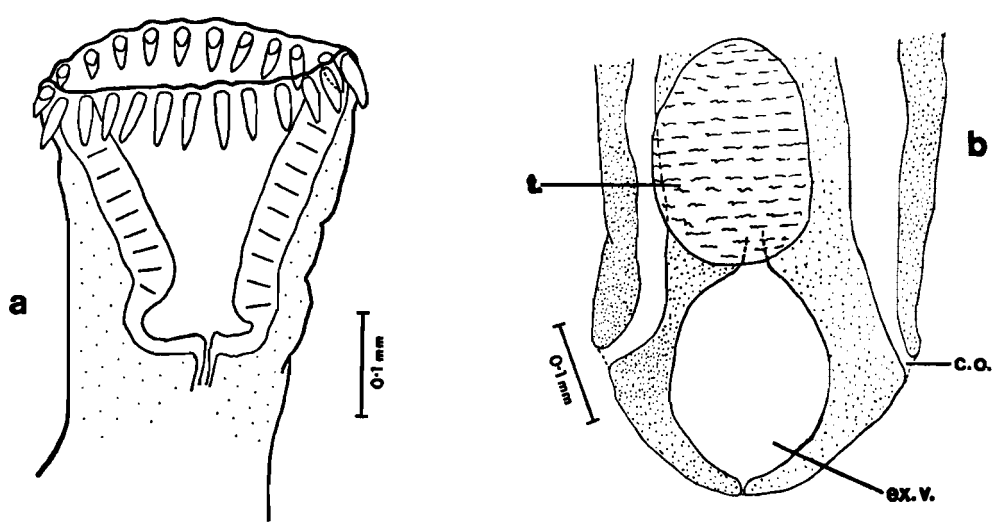


FIGURE 3

Acanthostomum productum. (a) cephalic region; (b) connection of intestinal caeca with exterior. *c.o.*, caecal opening; *ex.v.*, excretory vesicle; *t.*, testis.

specimens of *Acanthostomum gonocotyl* Dollfus and *A. productum* (Odhner) from African crocodiles, and many of *A. spiniceps* (Odhner) from African *Bagrus* in the collections of the British Museum (Natural History) all show either a distinct opening or an involution of the body-wall where the caeca terminate, suggesting a connection between the end of the caecum and the body-wall.

Six or seven species of *Acanthostomum* have been recorded from African crocodiles and freshwater fishes, but Nasir (1974) has recently placed all these species in the synonymy of *A. imbutiforme* (Molin, 1850), a parasite of Mediterranean fishes. On available evidence, it is exceedingly doubtful whether all six species from African freshwater hosts are synonymous, especially when it is realized that all known specimens from crocodiles invariably have 23 circum-oral spines, a figure that has not yet been found to be constant in specimens from African freshwater fishes.

Where known, the metacercariae of *Acanthostomum* occur encysted in the subcutaneous tissues of various fishes.

Family **Echinostomatidae**

Nephrostomum ramosum (Sonsino, 1895) Dietz, 1909

(Figures 4–5)

A single mature specimen was recovered from a grey heron (*Ardea cinerea*) at Marble Hall, and the following description is based on a whole mount of this specimen.

The body is elongate, somewhat ribbon-like and dorso-ventrally flattened. It is capped anteriorly by the characteristic armed head-crown of the echinostome trematodes. The total length of the body is about 17 mm and the maximum width 2,18 mm, at the level of the anterior testis. The width immediately behind the head-crown is about 1,5 mm, and from this point it slowly increases to the maximum width of 2,18 mm at the middle of the body, whence the width gradually decreases and finally the body tapers sharply. The surface of the body is aspinose, but this is, no doubt, due to spines having been lost. The head-crown is typically reniform, with a semi-circular ventral notch and a shallow dorsal depression. The crown measures up to 1,8 mm in transverse diameter, and bears 48 cuticular spines which are arranged in a single row dorsally and laterally, as shown in Figure 5, with a cluster of four peg-like spines disposed in a double row on each ventral lobe of the head-crown. The spines are largest on the ventral lobes (80 × 48 μm), and become smaller (73 × 37 μm) and more pointed along the lateral margin, with six small very stout ones (35 × 30 μm) along the dorsal depression on the head-crown. Spines are absent from the ventral indentation.

The oral sucker lies towards the anterior margin of the head-crown, and its shape is bluntly triangular with the narrow end directed postero-ventrally. The size of the oral sucker is 0,39 by 0,30 mm. The ventral sucker is well developed and somewhat funnel-shaped, with the narrow rounded margin directed posteriorly. It is situated at about one-eight of the body-length from the anterior end, 0,77 mm behind the head-crown, and is 1,48 mm in length and

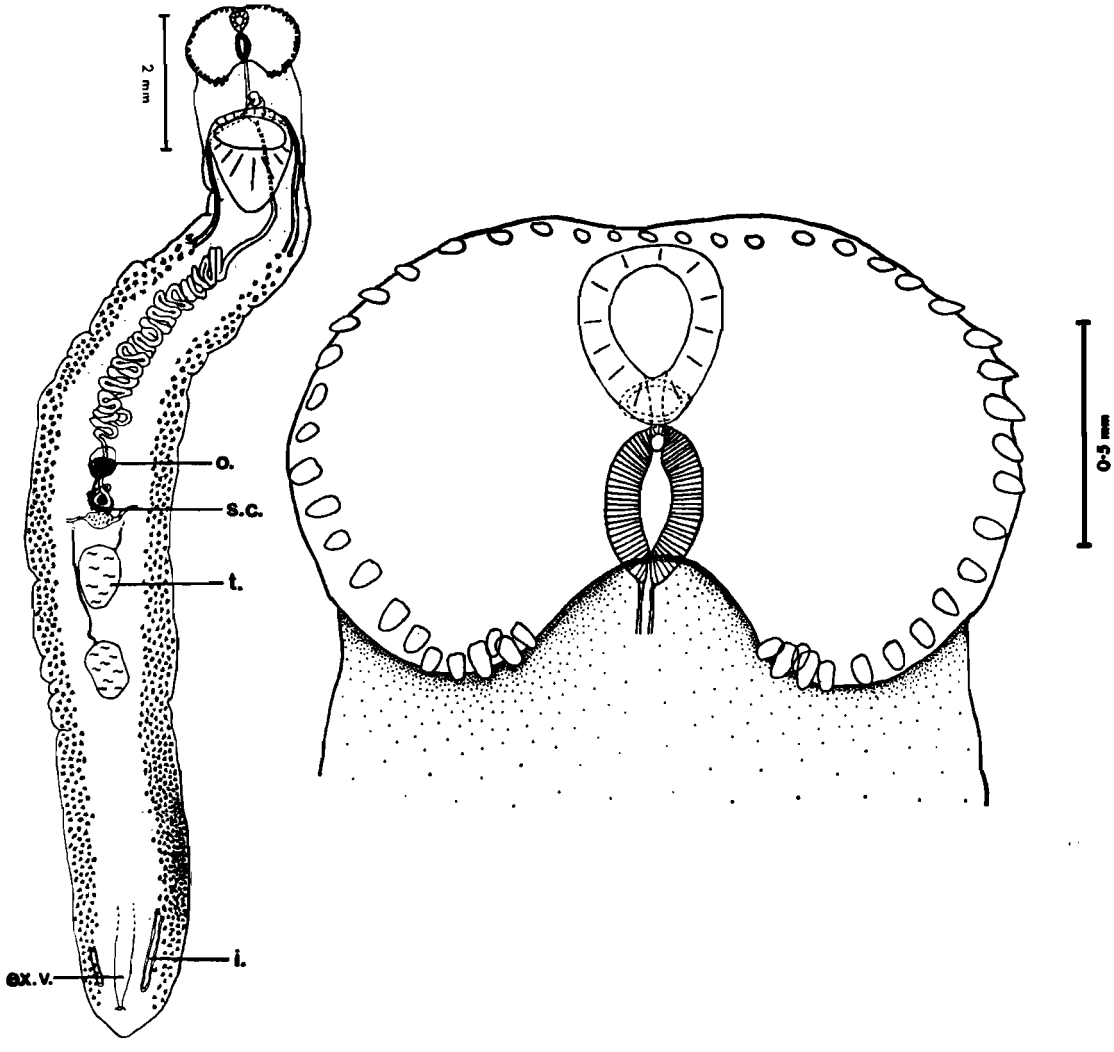


FIGURE 4 (left)

Nephrostomum ramosum (ventral view). ***ex.v.***, excretory vesicle; *i.*, intestinal caecum; *o.*, ovary; *s.c.*, 'shell-gland' complex; *t.*, testis.

FIGURE 5 (right)

Nephrostomum ramosum. Head-collar with spines (ventral view).

1,38 mm in width.

A very short, but distinct, thin-walled prepharynx, 85 μm long, enters a well-developed oval pharynx subterminally and ventrally. The anterior region of the prepharynx is surrounded by a ring of muscles which is about 0,1 mm in diameter. The pharynx is elongate-oval and measures 0,37 × 0,26 mm, with walls 80 μm thick. The oesophagus extends along the median line and bifurcates dorsally to the anterior border of the ventral sucker. The intestinal caeca are rather thin-walled and indistinct, but have a lumen about 80 μm wide and extend to the posterior end of the body.

There is a distinct excretory pore situated in the median line on the dorsal surface of the body, at about 0,27 mm from the hinder end. The excretory vesicle is Y-shaped, bifurcating at about midway between the posterior testis and the hinder end.

The genital pore lies in the median line immediately in front of the ventral sucker. In the present specimen the cirrus is partially everted through the pore and has a smooth surface. The cirrus-sac lies dorsally to the anterior border of the ventral sucker and contains, in addition to the cirrus, a pars prostatica and a coiled seminal vesicle. The sac is oval and measures 0,38 mm long and 0,34 mm wide.

The testes lie one directly behind the other in the posterior half of the body at about 2,3 mm and 1,8 mm from the hinder end respectively. They are compact, elongate-oval structures, the anterior testis being 0,86 × 0,55 mm and the posterior 0,86 × 0,53 mm. The vasa efferentia run forward from the anterior margin of each testis, but after a short distance their passage becomes obscured by surrounding tissues.

The ovary is also oval, 0,46 × 0,50 mm. It lies in the median line, with its posterior border at about 1 mm in front of the anterior testis, at a point approximately in the middle of the body. In the present specimen the nucleated tissue of the ovary has degenerated until the organ occupies only about one half of its original area, which can be made out by the presence of a tunic which presumably invested the fully-developed ovary. The oviduct leaves the posterior edge of the ovary, but much of its course is obscured by the "shell"-gland complex and folds of the uterus. No details of Laurer's canal could be made out. The "shell"-gland complex exists as a diffuse area of numerous glands lying between the ovary and the vitelline reservoir, and is surmounted by coils of the uterus.

The vitellaria consist of many compact, globular masses ranging from 50 to 90 μm in diameter. They extend in two lateral fields from the level of the excretory pore forward to within about 0,65 mm of the ventral sucker. A yolk-duct from each field opens into an oval vitelline reservoir measuring 0,13 × 0,39 mm, which lies in the median line, 0,52 mm behind the ovary.

The uterus is thrown into several transverse folds lying between the intestinal caeca and between the ovary and the ventral sucker. It is filled with eggs 95–105 μm × 57–62 μm in size.

The shape of the body of the worm described above is different from that normally encountered in this species. Usually, the body of a fully-mature worm is elongate-oval, with the maximum width, which occurs at about the level of the ovary, being at least one-and-a-half times greater than the transverse diameter of the head-crown. The present specimen is rather elongate and the transverse diameter of the head-crown is only a little less than the maximum

width of the body, but the histological condition of the specimen suggests that it was much relaxed when fixed, and thereby may have assumed an elongate shape. Moreover, *N. ramosum* appears to be normally a parasite of the cattle-egret (*Bubulcus ibis*), and possibly *Ardea cinerea* is an unusual host that has influenced the shape of the present worm.

The only details known, so far, of the life-history of *N. ramosum* are given by Azim (1934), who saw echinostome cercariae emerging from *Planorbis boissyi* in Egypt and found that, under laboratory conditions, they invaded tadpoles through the skin and encysted in the subcuticular tissues.

Mji (1951) has proposed the name *Nephrostomum ramosum* var. *tyumiensis* for trematodes found in the duodenum and ileum of *Ardea melanocephala* from the Tyumie Valley in Cape Province. This variety was distinguished from the typical form described by Dietz (1910) by a difference in the configuration of the Y-shaped excretory vesicle, which is normally exceedingly variable, by the shape of the oral sucker, by the length of the oesophagus, by the shape of the testes and by the size of the spines in the depression of the head-crown. All the differences enumerated by Mji are exceedingly superficial and have no systematic importance whatever, and for this reason the variety *tyumiensis* should be considered identical with typical specimens of *N. ramosum*.

A new species of *Nephrostomum*, *N. legonum*, was erected by Ukoli (1967) for specimens obtained from *Bubulcus ibis* in Ghana. This new species was said to differ from *N. ramosum* in the possession of 50 instead of 46–48 spines on the head-crown, including six corner-spines instead of four or five, and in a well-marked posterior process or tail. Usually, the head-crown of *N. ramosum* bears a row of 48 spines, but occasionally 46, 47, 49 or 50 may be present. Again, there may be four or five spines in each corner-group, but specimens fixed under pressure may be thought to have six spines in each group. Often the apparent difference in the number of spines in each group is a matter of interpretation, unless it is realized that the corner-spines are arranged in two alternate rows, and that one of them is a continuation of the main row of spines. The tail or posterior process is not an unusual feature among echinostomes, but its presence is fortuitous and is probably dependent upon the degree of relaxation of the body and the terminal position of the excretory pore at the time of fixation. It seems that the features used to substantiate the erection of a new species are not constant and therefore *N. legonum* Ukoli, 1967, is here regarded as a synonym of *N. ramosum*.

Family **Clinostomidae**

Euclinostomum heterostomum (Rudolphi, 1809)

(Figure 6 a–b)

Adult.

A single mature specimen was recovered from beneath the tongue of a grey heron (*Ardea cinerea*) obtained at the Fisheries Research Station in the Lowveldt Reserve. In the collections of the British Museum (Natural History) there are several specimens of this trematode from

the oesophagus of the hammerhead (*Scopus umbretta*) from Lydenburg, Transvaal, and from Salisbury, Rhodesia, a host not hitherto recorded for *E. heterostomum*.

The body of a fully-mature adult of this species is elongate, rounded posteriorly, and somewhat flattened at the anterior extremity, which bears a plain cephalic depression forming

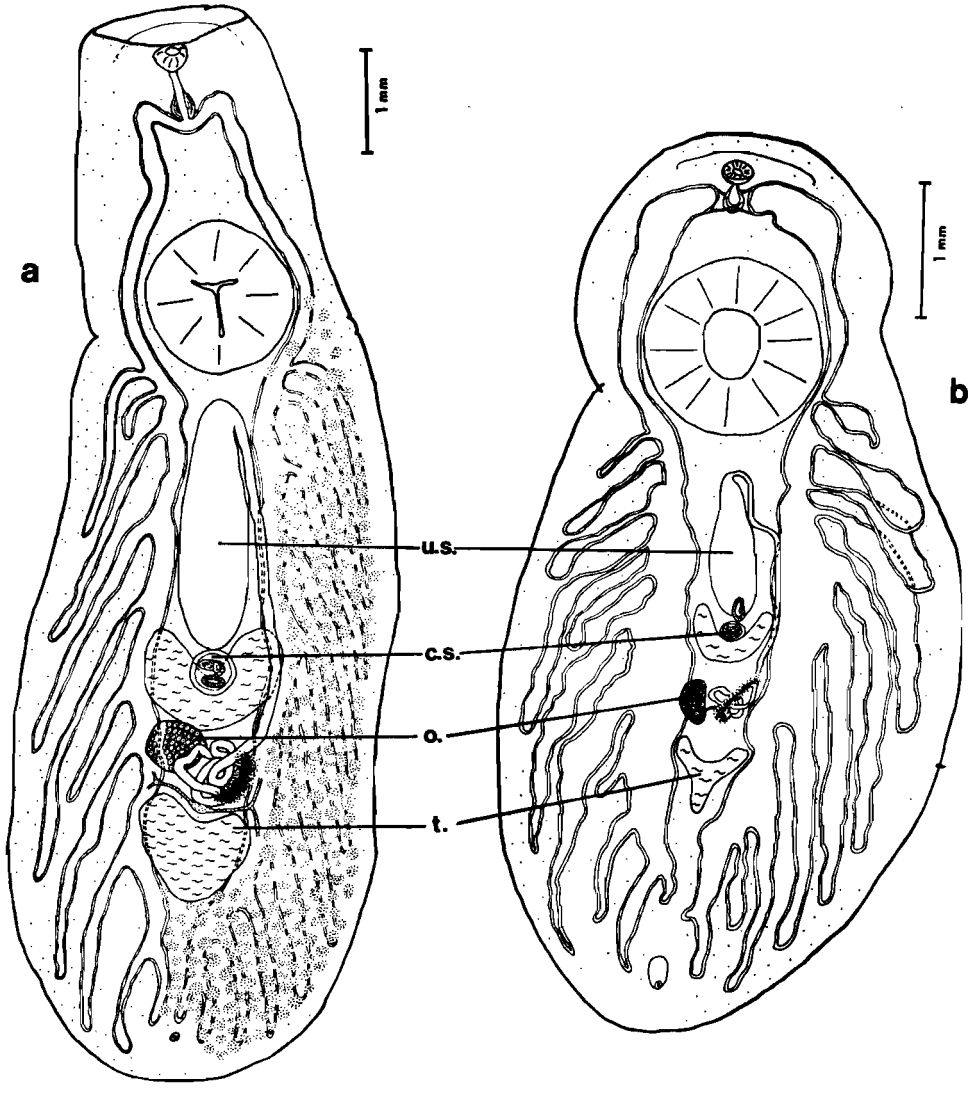


FIGURE 6
Euclinostomum heterostomum (ventral view). (a) adult; (b) metacercaria. *c.s.*, cirrus-sac; *o.* ovary; *t.*, testis; *u.s.*, uterine sac.

a collar 0,8–1,4 mm in diameter. There is often a shallow constriction around the body at the level of the ventral sucker, and forward from this point the body may taper slightly. It varies from 6,7 to 10,5 mm in length and from 2,9 to 3,5 mm in maximum width, at the level of the anterior testis in the hinder fourth of the body. The cuticle is smooth.

The oral sucker lies in a mound arising from the floor of the cephalic depression. It often appears to be weakly developed and measures 0,31–0,36 mm in length and 0,27–0,40 mm in width. The ventral sucker is a well-developed muscular organ situated at about the anterior fourth of the body-length. It varies between 1,3 and 1,6 mm in diameter and gives an oral/ventral sucker ratio of 1:2,5–3,5. The aperture of the sucker is rounded or triangular in outline, but may often be reduced to a T-shaped opening, which may suggest a trilobed organization of the muscles of the wall of the sucker.

Apparently there is no pharynx, despite the assertion of Dennis & Sharp (1973), and the oral sucker leads directly into an oesophagus, the hinder region of which is provided with a relatively thick musculature forming a bulbous structure. A thick mass of gland-cells invests this bulb, and the ducts from these cells pass through the walls of the bulb and open into its lumen. Immediately following this muscular bulb, the oesophagus bifurcates and opens directly into a pair of intestinal caeca that reflex to run antero-laterally for a short distance before turning abruptly to proceed almost to the posterior end of the body. Behind the level of the ventral sucker the intestine repeatedly gives off 10 to 13 finger-like appendages, which are directed postero-laterally and lie roughly parallel to each other in a diagonal plane. These appendages may also branch occasionally, and the hinder end of each intestinal caecum appears to bifurcate.

The excretory pore is situated in a dorsal and median position near the posterior end of the body. In specimens of this trematode examined by the writers, the excretory vesicle appears to have a very thin wall and is not sufficiently differentiated from the surrounding tissue for details of its shape to be made out in whole mounts.

The genital pore is represented by a slit in the body-wall and is situated in the median line at about the junction of the middle and hinder thirds of the body-length. It leads into a shallow atrium, at the base of which lie the openings of the cirrus-sac and metraterm. The cirrus-sac is rounded, pyriform or oval, and well developed. It is relatively large, with its greater diameter in a dorso-ventral plane, and lies in the median line ventrally to the foremost, somewhat U- or V-shaped, testis or in the crotch of this testis. The cirrus-sac contains a bipartite seminal vesicle.

The two testes lie close together, one directly behind the other, between the intestinal caeca and between 1,8 and 3,4 mm from the hinder end of the body. The posterior testis is reniform, with lobes directed forward, and measures up to 1,15 mm in transverse diameter and up to 0,8 mm in length. The anterior testis is of similar size and also reniform, but the lobes are so extended as to be almost U- or V-shaped in outline.

The ovary is situated to the right of the median line between the testes and may partially overlap the intestinal caecum on that side. It is a compact, rounded organ with a diameter of up to 0,50 mm. A "shell"-gland complex is not sufficiently differentiated for its structure to be interpreted with any degree of accuracy in whole mounts. The vitellaria consist of a large number of closely-packed follicles, 50 to 60 μm in diameter. They are disposed laterally

from about the hinder level of the ventral sucker to the posterior end of the body, overlying the intestinal caeca and their branches dorsally and ventrally. In addition, the vitelline follicles are confluent in the median line behind the posterior testis, but leave the area around the excretory pore clear. Further, in contracted specimens, the vitellaria may also be confluent in the median line immediately behind the ventral sucker. Ducts from the follicles lead into a pair of longitudinal canals, one anterior and the other posterior, lying ventral to each intestinal caecum. These canals unite to form on each side a transverse duct, which crosses the body to unite with its fellow immediately in front of the hinder testis. At their junction in the median line, the transverse canals swell to form a distinct yolk-reservoir.

The uterus arises from the oviduct and is thrown into a few short coils within the space bounded by the testes and the intestinal caeca. From this region it extends round the left-hand margin of the anterior testis, along the ventral side of the left-hand caecum and then towards the median line to just below the level of the ventral sucker. Here it enters a uterine sac subterminally. The sac is dilated and elongate, tapering anteriorly, and has relatively thick walls. It lies between the intestinal caeca and extends from behind the ventral sucker to the cirrus-sac. The metraterm is not clearly visible, but appears to leave the hinder region of the sac subterminally, on the left-hand side. The uterus, and much of the uterine sac, is filled with large, oval eggs, which are slightly flattened at the opercular pole. They measure from 127 × 74 μm to 135 × 77 μm.

Metacercaria (Figure 6b)

Two metacercariae of this species were found in the tissues of *Sarotherodon* (*Tilapia*) *mossambicus*, also from the Lowveldt Reserve. In many respects the present immature forms resemble the adult, notably in the number and form of intestinal diverticula and in the point of entry of the uterus into the uterine sac. Both specimens are somewhat contracted, each having an almost oval outline, with a shallow constriction at the level of the ventral sucker, making the outline of the body reminiscent of a key-hole. The length of the body in the two specimens is 5,8 and 7,12 mm, and the maximum width, at the level of the anterior testis, 2,84 and 3,30 mm, respectively. The cephalic depression is 0,13–0,18 mm in transverse diameter. Cercarial eyespots, mentioned by Fischthal & Kuntz (1963), are not apparent. The oral sucker has a diameter of 0,21–0,26 mm and is funnel-shaped or bulbous. One of the specimens has a triangular aperture to the ventral sucker, but this condition is not indicated in the other specimen. The diameter of the ventral sucker is 1,25–1,30 mm. The oral/ventral sucker ratio is 1:5–6. The morphology of the digestive system of the metacercaria is very similar to that of the adult. It may be noted, however, that in both metacercariae the gut is filled with food so that the intestinal limbs are somewhat expanded.

The excretory pore lies 0,34 mm from the hinder end of the body in both specimens. In one metacercaria there is a sausage-shaped bladder (0,24 × 0,13 mm) extending anteriorly from the excretory pore. In both specimens the genital atrium is situated in the median line, anterior to the cirrus-sac. The atrium is surrounded by muscles and gland-cells. The cirrus-sac is well developed and measures about 125 μm × 170–220 μm. It lies at the base of the crotch of the anterior U-shaped testis.

In the metacercaria, as in the adult worm, the testes are disposed in tandem, but are

more slender than in the adult so that the anterior testis is definitely U-shaped, whilst the posterior one has the form of a 'Y' with a very short stem or the outline of an inverted triangle. Their dimensions are 0,42–0,43 mm in length and 0,48–0,55 mm in overall width for the anterior testis, and 0,33–0,54 mm in length and 0,46–0,6 mm in width for the posterior testis. Respectively, the testes are situated 1,28 and 1,94 mm from the hinder end of the body in the smaller specimen, and 1,73 and 2,92 mm in the larger.

The ovary, which lies at about midway between the testes, is oval and measures 0,12–0,13 mm by 0,25–0,26 mm. There is an expansion of the oviduct to the left of the ovary which is a partly-formed seminal receptacle. Vitelline follicles are distributed as in the adult, although they are much smaller. A well-developed uterus and uterine sac are also present. The latter is elongate-oval with a transverse diameter of about 0,11 mm. The entrance of the uterus into the sac is immediately subterminal and anterior.

So far as is known, the adult of this species occurs naturally in ciconiiform birds in southern Europe, eastwards to the Indo-Malaysian region and over the whole of Africa. The worm has also been found naturally and experimentally in pelecaniform birds in India and West Africa, but in each case the parasite seemed not to have reached maturity, and its growth appeared to have been stunted, which suggests that pelecaniform birds might not be normal hosts of *Euclinostomum heterostomum.*

With the exception of the sporocyst, the developmental stages in the life-history of *Euclinostomum heterostomum* have been recognized, and the metacercaria is known to occur embedded in the liver, or encapsulated on the surface of the kidneys, mesenteries, small intestine or in the muscles of the coelomic wall of various freshwater fishes. In Africa, the primary second intermediate hosts appear to be clariid, silurid and cichlid fishes, but a metacercaria of this parasite from *Barbus pallidus* in the Zwartkops River, Uitenhage, Cape Province, is in the helminthological collections of the British Museum (Natural History). It is also worthy of mention that Lombard (1968) found *Euclinostomum* metacercariae embedded in the tissues of various species of *Tilapia* in the Transvaal.

Euclinostomum sp. indet. (metacercaria)

(Figure 7)

A single specimen was recovered from the body-cavity of *Clarias gariepinus*. It is large with a total length of 19,3 mm and a maximum width of 5,37 mm at the level of the anterior testis. The body is elongate, somewhat dorso-ventrally flattened, with rounded ends. The cuticle is smooth. The oral sucker is bulbous, with a diameter of 0,40 mm, and is situated on the floor of a cephalic depression, which measures 0,75 mm in width and 0,22 mm in depth. The ventral sucker has a diameter of 1,75 mm, is rounded and well developed, with a triangular aperture, and the oral/ventral sucker ratio is about 1:4,4.

The oesophagus is about 0,27 mm in length and opens posteriorly into an elliptical muscular bulb measuring 0,275 × 0,155 mm. The intestine leaves the muscular bulb ventrally and almost immediately bifurcates to produce two limbs which pass backwards to the posterior

end of the body. There are 16 finger-like postero-lateral branches to the right intestinal caecum and 14 similar branches to the left caecum. The main limbs are swollen with food giving rise to bulbous swellings at intervals. The excretory pore lies in the median dorsal plane at 0,58 mm from the posterior end of the body. No excretory bladder or ducts have been made out in the present specimen. The genital pore is a transverse slit which opens into a genital atrium lying over the anterior part of the cirrus-sac. The sac itself is rounded, with a diameter of 0,43 mm, and contains a bipartite seminal vehicle. Both testes are situated in the posterior third of the body, the hinder one being within the last sixth of the total length of the body, 2,24 mm from the posterior end. They are transversely elongate and more or less U-shaped. The anterior testis lies at about 4,7 mm from the posterior end of the body and measures 2,2 mm in length and 0,3 mm in thickness, which is more or less uniform along its entire length, whilst the posterior testis has a length of 1,06 mm and a thickness of 0,20 mm. The ovary lies between the two testes, a little to the right of the median line. It is small and oval, measuring 0,34 × 0,16 mm. An oviduct leaves the dorsal side of the ovary near its hinder end, and then turns and enters an area occupied by diffuse glandular material destined to form the "shell"-gland complex and the seminal receptacle. From this area, the uterus extends forward, following the left-hand limb of the gut, although anterior to the foremost testis it lies between the caeca. At a point 2,85 mm posterior to the ventral sucker, it enters the uterine sac subterminally. This sac is elongate (6,9 mm) with an average width of 0,08 mm. The posterior end of the uterine sac is rounded and almost reaches the cirrus-sac. A short, rather indistinct, metraterm with thin walls leads from a point 100 μm forward from the hinder end of the uterine sac to the genital atrium. Many heavily-nucleated, ovoid, vitelline follicles, 20 × 17 μm, are scattered in the parenchyma above and below the intestinal caeca. They extend from just behind the ventral sucker to the hinder end of the body, where they also occur between the intestinal caeca behind the posterior testis, although they are absent from the area around the excretory pore.

Fischthal & Kuntz (1963) proposed the new name *Euclinostomum dollfusi* for two mature specimens, determined by Dollfus (1950) as *Euclinostomum heterostomum* (Rud.), from *Ardea goliath* in Zaire. According to Dollfus' Figure 52, one of these specimens possesses no prepharynx, but an oesophagus, and the uterus opens into the middle region of the uterine sac; features which the American authors apparently consider to be of sufficient significance for specifically separating the specimens from *E. heterostomum*. Dollfus also figures (Figure 53) an immature specimen from the same host, but the worm appears to have no oesophagus and the uterus opens into the anterior region of the uterine sac, features that are accredited to *E. heterostomum*. It is noted, however, that in specimens of *Euclinostomum heterostomum* from *Scopus umbretta* in Rhodesia, and examined by the present writers, the uterus opens into the middle region of the uterine sac when containing eggs, but into the anterior region of the sac when no eggs are present. Otherwise, the two sets of specimens are identical.

The immature specimen depicted by Dollfus agrees exceedingly well with the unspecified specimen described above in its larger size and particularly in the possession of 14 to 16 postero-lateral branches to each intestinal caecum. In these features this form appears to differ from the metacercariae of *E. heterostomum*, which is distinctly smaller and has only 8 to 12 branches to each caecum. Whether or not the present worm is specifically distinct from

the latter species cannot at the moment be determined satisfactorily, for the number of intestinal branches might increase with the size of the worm.

It is perhaps opportune to mention here that clinostome or "yellow-grub" disease appears to be very common and widespread among freshwater fishes in Central Africa. Through the lack of information it is not yet possible to state with certainty whether these trematodes are as common among similar fishes in southern Africa, but there is no reason to assume not. In the senior writer's experience, where these worms are found, there seems to be a high frequency of infestation in fishes, and this is probably due to the unusually high production of embryos in the redial generation in the life-history of these flukes. A mother-sporocyst, for instance, produces one redia that is followed by at least two generations of rediae, the last of which may completely fill the digestive gland of its molluscan host. In North America it has been found that a *Helisoma* snail with a half-inch shell-diameter harboured about 2 000 rediae of *Clinostomum marginatum*, whilst another snail of the same genus, but with a shell-diameter of one inch, harboured about 4 000 rediae of the same species of fluke, thus suggesting that the number of rediae present increases with the size of the snail-host. Since cercaria-producing rediae were each found to contain up to 300 fully-formed cercariae, as well as embryos in various stages of development, it is clear that an enormous number of cercariae may be developed. A single infested snail might therefore contain more than 500 000 fully or partially-developed cercariae, and during the course of such an infestation many millions of free-swimming cercariae would be produced. The casualties among these cercariae are undoubtedly enormous, but a large number still survives to account for the high infestation by metacercariae in piscine hosts.

In some regions of the world, fish carry such heavy infestations of these grubs as to be condemned for human consumption, but this appears to have been done purely for aesthetic reasons. It should be noted, however, that there are several records of domestic cats harbouring adult clinostomes, which are mainly sanguinivorous. Moreover, there are cases on record of acute pharyngitis in man in Israel (Witenberg 1944) and Japan (Yamashita 1938) due to clinostomes. Such infestations very probably arose from eating uncooked or only partially-cooked fish.

Family **Strigeidae**

Apharyngostrigea cornu (Zeder, 1800) Ciurea, 1927

(Figure 8)

The following description is based upon specimens recovered from the intestine of a grey heron (*Ardea cinerea*) at Marble Hall. Two whole mounts and longitudinal serial sections of the trematode have been examined. The measurements given below have been taken from a single whole mount.

The body is arcuate in lateral view, convex ventrally, concave dorsally, and measures

6,9 mm in length. It is divided into an expanded anterior segment, or forebody, which is somewhat cup-shaped, and an elongate sub-cylindrical hindbody. The ratio of the length of the anterior segment to that of the posterior segment is 1:3,6. The whole body shows a dorso-ventral curvature and is without spines.

The cup-shaped forebody is about 1,5 mm long, with a diameter of 1,26 mm. Its dorsal wall is thicker than the ventral wall, since the former contains the anterior part of the gut and also the suckers. The cup encloses a well-developed tribocytic organ or "holdfast" consisting of two lobes of tissue arising from the interior surface of its dorsal wall, immediately behind the level of the ventral sucker. Both lobes are flattened and tongue-like and lie in a dorsal and a ventral plane. They extend to the anterior periphery of the forebody and may protrude beyond it. In the posterior region of the forebody there is a large, lobed, roughly oval proteolytic gland, which measures 0,34 × 0,26 mm and opens into the cup-shaped forebody between the bases of the lobes of the holdfast.

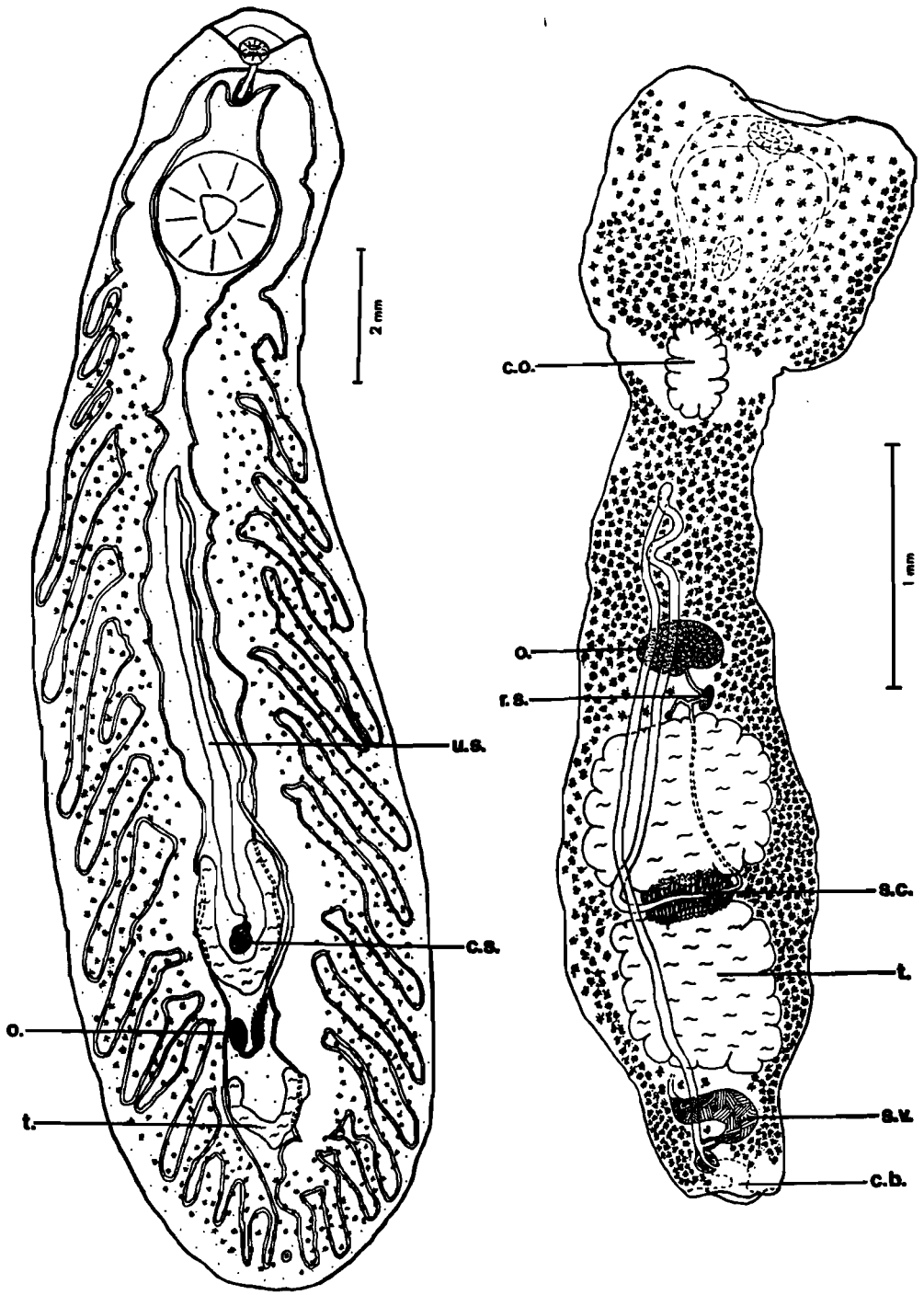
The oral sucker is globular and situated subterminally on the inner surface of the dorsal wall of the forebody. The ventral sucker lies at 0,57 mm from the anterior end of the body, at the base of the pocket formed by the dorsal lobe of the tribocytic organ and the dorsal wall of the forebody. The oral sucker is 0,17 × 0,15 mm and the ventral sucker 0,20 × 0,15 mm, giving a sucker ratio of about 1:1. Immediately behind the oral sucker lie two masses of gland-cells, each mass discharging its secretions into the "cup" of the forebody through a separate pore situated on either side of the median line.

The hindbody is about 5,4 mm long. It has a maximum width of about 1 mm at the level of the anterior testis and tapers to a width of 0,6 mm immediately behind the anterior segment. At the posterior end of the body there is an eversible copulatory bursa.

There is no pharynx, as the generic name suggests, but immediately behind the oral sucker the oesophagus may be somewhat dilated. The oesophagus is short and the gut bifurcates behind the level of the ventral sucker. The caeca are narrow and extend dorsally and posteriorly to terminate near the copulatory bursa.

The two testes lie close together, one directly behind the other, in the hindbody. They are large and occupy over one quarter of the total length of the body. In the present specimens, the testes have degenerated somewhat and their exact extent or shape cannot be easily determined in the whole mount. In serial section, however, they seem to be multilobed organs. Their approximate dimensions are 0,47 mm long and 0,52 mm wide for the anterior testis and 0,60 mm long and 0,60 mm wide for the posterior testis. The elongate, folded, seminal vesicle lies close behind the posterior testis. It is followed by a short ejaculatory duct, the proximal portion of which is endowed with strong longitudinal muscles and, as is usual in this group, there is apparently no pars prostatica.

The ovary lies in front of the testes, at about halfway along the hindbody. It is transversely oval, 0,21 × 0,32 mm. From the ovary, an oviduct passes posteriorly to a rounded receptaculum seminis of variable size. Immediately following this union a short Laurer's canal occurs, and the sectioned specimen shows a mass of sperm and ovarian material issuing through the external opening of the canal (Figure 17). Proceeding posteriorly, the oviduct continues to a point between the testes where it forms an oötype invested with a multi-cellular Mehlis' gland, and receives the common vitelline canal, the whole constituting the "shell"-gland



complex.

The vitellaria are follicular and distributed through much of the body. In the forebody they lie in the dorsal wall of the segment, in both lobes of the tribocytic organ, and extend forward to the oral sucker, but are absent from the ventral wall. They extend posteriorly, ventrally and dorsally through the hindbody to the copulatory bursa, except dorsal to the testes where only a few widely-scattered follicles may occur. The continuity in the distribution of the follicles appears to be somewhat interrupted at the junction of the two segments of the body. There is a small yolk-reservoir lying between the testes.

The uterus emerges from the oötype as a thin-walled canal which passes forward, ventral to the anterior testis, as far as the junction of the anterior and posterior segments of the body. It then turns sharply to descend in the ventral parenchyme, to the posterior end of the body in an almost straight line. The ejaculatory duct unites with the uterus to form a hermaphroditic duct, which opens at the top of a broad, but shallow muscular genital papilla or cone, lying in a spacious copulatory bursa. This bursa opens to the exterior terminally at the hinder end of the body.

The uterus contains large eggs, measuring 88–95 μm by 55–63 μm. Many of the eggs contain embryos.

Apharyngostrigea cornu is essentially parasitic in the intestine of ciconiiform birds, and has been recorded from these birds in central and North America, Europe, Asia and Africa. Hitherto, there appear to be only two records of this worm from Africa, one from *Bubulcus ibis* in Morocco (Joyeux & Gaud 1945) and the second from *Ardea cinerea* in Malagasy (Richard 1964).

In Europe, the metacercaria of *A. cornu* has been found encysted in various organs in the body-cavity of several species of cyprinid fishes, and through the kindness of Mr B. G. Connelly of the Fisheries Research Station in the Matopos National Park, Rhodesia, the senior writer has examined *Apharyngostrigea* metacercariae found encysted in the gut-wall of *Barbus marequensis*, and closely resembling those of *A. cornu* described by Mattheis & Odening (1969). In Africa, it is likely that the metacercariae of this trematode will also be found in fishes of families other than the Cyprinidae.

Family **Diplostomidae**

Pseudoneodiplostomum bifurcatum (Wedl, 1862)

(Figure 9)

This description is based upon six specimens, two of them whole and four incomplete. The

FIGURE 7 (left)
Euclinostomum sp.indet. (ventral view). *c.s.*, cirrus-sac; *o.*, ovary; *t.*, testis; *u.s.*, uterine sac.

FIGURE 8 (right)
Apharyngostrigea cornu (ventral view). *c.b.*, copulatory bursa; *o.*, ovary; *r.s.*, receptaculum seminis; *s.c.*, 'shell'-gland complex; *s.v.*, seminal vesicle; *t.*, testis; *t.o.*, tribocytic organ.

material was obtained from the intestine of a Nile crocodile (*Crocodylus niloticus*).

The worm is long and narrow, with a total length varying between 5,5 and 7,8 mm. The body is divided into a leaf-like dorso-ventrally flattened forebody, which is spatulate in outline, and a sub-cylindrical hindbody. The cuticle is aspinose. The forebody is about two-fifths of the total length of the worm, and measures between 2 and 3,3 mm in length and between 0,58 and 0,80 mm in maximum width. The posterior region of the forebody is more rounded than the anterior region, which tapers towards the oral sucker. The forebody bears upon its ventral surface the oral and ventral suckers, as well as a well-developed tribocytic organ. This organ lies in the posterior half of the forebody. It is elongate, measuring 0,85 × 0,2 mm to 1,0 × 0,25 mm, and provided with a number of finger-like papillae on the rim of its ventral aperture. The oral sucker is subterminal, globular and small, with a diameter of 65 to 70 μm. The ventral sucker lies more or less at the middle of the forebody. It is shallow, rounded or transversely oval, with a diameter of 0,115 to 0,125 mm. The oral/ventral sucker ratio is about 1:1,75.

There is no prepharynx. The oval thick-walled pharynx lies immediately behind the oral sucker. It measures 52 × 34 μm to 63 × 42 μm. An oesophagus, measuring between 0,17 and 0,26 mm in length, runs posteriorly from the pharynx for a short distance before bifurcating to form a pair of intestinal caeca that descend the length of the body and terminate blindly in the posterior region.

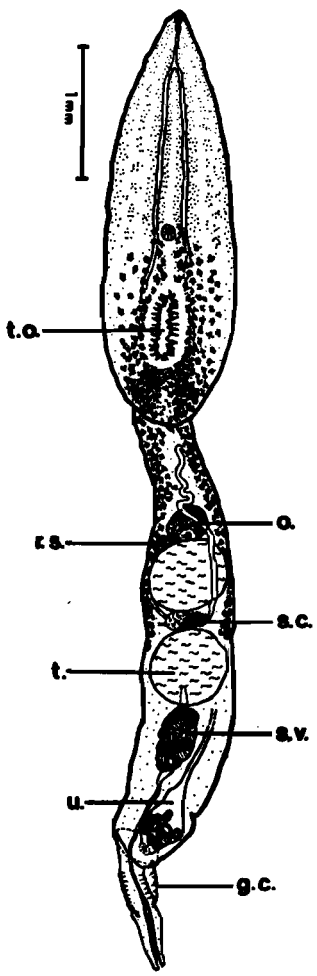
The hindbody measures from 3,0 to 5,6 mm in length and from 0,55 to 0,8 mm in maximum width, which occurs at the level of the anterior testis. It contains the reproductive organs of the worm, and at its posterior end there is a well-developed, spacious, copulatory bursa containing a long genital cone.

The two testes lie in tandem in the middle third of the hindbody. Both are large, with an outline which is usually rounded, but occasionally oval. The anterior testis is slightly smaller than the posterior; the former varying from 0,29 × 0,30 mm to 0,46 × 0,60 mm, and the latter from 0,31 × 0,30 mm to 0,58 × 0,62 mm. Immediately behind the posterior testis there is an elongate, compactly-coiled seminal vesicle that measures about 0,6 mm long and 0,2 mm wide. An ejaculatory duct leaves the seminal vesicle and passes posteriorly through the axis of the genital cone to open at its apex. This cone is strongly muscular and may be retracted within the copulatory bursa or be protruded through the subterminal opening of the bursa. When protruded the cone may reach a length of 1,2 mm.

The ovary lies immediately in front of the foremost testis and in the anterior third of the hindbody, between 0,55 mm and 0,80 mm from the junction of the forebody and the hindbody. The ovary is rounded or nearly so, and measures roughly 0,17 × 0,17 mm to 0,28 × 0,28 mm. There is a convoluted receptaculum seminis situated laterally between the ovary and the anterior testis. It is somewhat variable in shape and size. In some of the specimens Laurer's canal is clearly visible, and opens dorsally in the midline between the ovary and anterior testis. The oviduct descends to the area between the testes, where it passes into the oötype. In this area also lies a rounded, or transversely oval, vitelline reservoir, measuring up to 0,16 × 0,16 mm, into which opens two yolk-ducts, one from each vitelline field. The vitellaria consist of numerous irregularly-shaped follicles extending laterally from the anterior margin of the hinder testis to the ventral sucker. Immediately behind the tribocytic organ the follicles are

confluent in the median line, and this union, which occurs both ventrally and dorsally, may extend posteriorly to the ovary. Further, the anterior follicles tend more towards the median line than to the margin of the forebody.

From the oötype, the uterus ascends, ventral to the anterior testis and ovary, following a somewhat winding course almost to the anterior end of the hindbody. It then turns to descend in an almost straight course to the posterior end of the body, where it opens to the



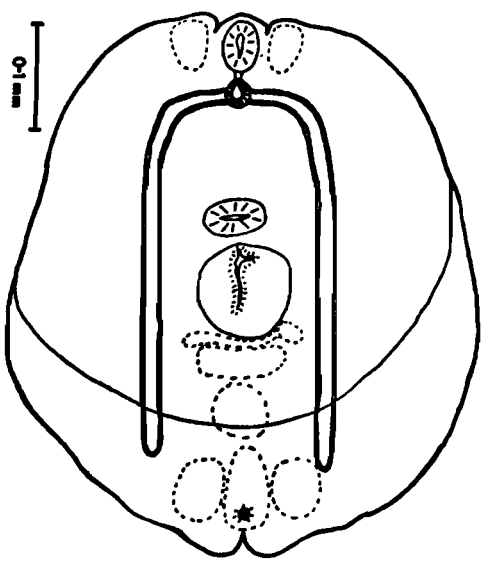


FIGURE 9 (left)

Pseudoneodiplostomum bifurcatum (ventral view). *g.c.*, genital cone; *o.*, ovary; *r.s.*, receptaculum seminis; *s.c.*, 'shell'-gland complex; *s.v.*, seminal vesicle; *t.*, testis; *t.o.*, tribocytic organ; *u.*, uterus.

FIGURE 10 (right)

Diplostomum type I. Metacercaria from mesenteries (ventral view).

exterior subterminally through a muscular uterine pore in the wall of the copulatory bursa. Before reaching the pore, the uterus is dilated and usually encloses ten or more eggs. The eggs are oval, measuring 110 × 82 μm. They are operculate and many contain embryos.

The excretory bladder appears to be trifurcate, with a narrow canal from each limb extending forward, one in the median line, and a pair lateral to the intestinal caeca, as far as the pharynx where the three canals unite. Particularly in the anterior region of the forebody, the lateral canals give rise to an anastomosing system of secondary canals.

Although the life-history of this trematode has not yet been elucidated, it is probable that its metacercaria is like that of the closely-related form *Pseudoneodiplostomum thomasi* (Dollfus, 1935), which, according to Fischthal & Thomas (1972), occurs encysted in the fat-bodies, kidneys, mesenteries and other organs of freshwater fish.

DIPLOSTOMID METACERCARIAE

(Figures 10–12)

Three kinds of diplostome metacercariae were encountered in *Clarias gariepinus*, two of them among the mesenteries and the third only in the cranial cavity in front of the brain. Two of these forms are recognizable as *Diplostomum*-type larvae and the other as a *Neodiplostomum*-type.

The *Diplostomum*-type I from thin-walled cysts in the mesenteries (Figure 10) is dorso-ventrally flattened and leaf-like. It is somewhat discoid in outline and measures 0,53 mm in length and 0,46 mm in maximum width. The body is divided into an anterior segment or fore-body and a posterior segment, hindbody, or caudal process, but the latter is variable and relatively small with a terminal notch on its posterior margin. The anterior region of the forebody shows very shallow transverse ridges of cuticle, which may, however, be due to a slight shrinkage of the body-wall. The oral sucker is subterminal and has a diameter of 58 μm. The pseudosuckers are scarcely noticeable as a pair of glandular pads situated alongside the oral sucker. A ventral sucker is situated at a distance of about 0,18 mm from the anterior end of the body, at approximately the junction of the first and second thirds of the total length of the body. It is transversely elongate with dimensions of 35 × 43 μm. Close behind the ventral sucker lies a somewhat rounded tribocytic organ, 87 μm in diameter. A short pre-pharynx leads into an inconspicuous rounded pharynx that immediately opens into the intestinal bifurcation, from which the intestinal caeca run transversely for a short distance before turning sharply to descend almost to the posterior end of the body. Between the ends of the caeca lie the genital primordia. The excretory vesicle appears to be a bilobed structure situated behind the intestinal caeca.

This type of metacercaria more frequently occurs in the eyes and central nervous system of freshwater fishes. In some instances, the host will produce a capsule of connective tissue around the larva. Where known, the diplostomulum larva develops to an adult in piscivorous birds or mammals.

The *Diplostomum*-type II (Figure 11) occurred unencysted in the cranial cavity in front

of the brain and was sent to the senior writer by Dr Anna Verster of the Veterinary Research Institute, Onderstepoort. This larva appears to be very common in *C. gariepinus* collected from the river-systems of central and southern Transvaal and in some of these districts the frequency of infestation is as high as 100 per cent.

The body is rather elongate and distinctly constricted into a dorso-ventrally flattened, elongate-oval forebody and a shorter, sub-cylindrical hindbody. The body varies between 0,81 and 0,85 mm in length and from 0,2 to 0,22 mm in maximum width, which occurs at about the middle of the forebody, whilst the width of the hinder body reaches to about

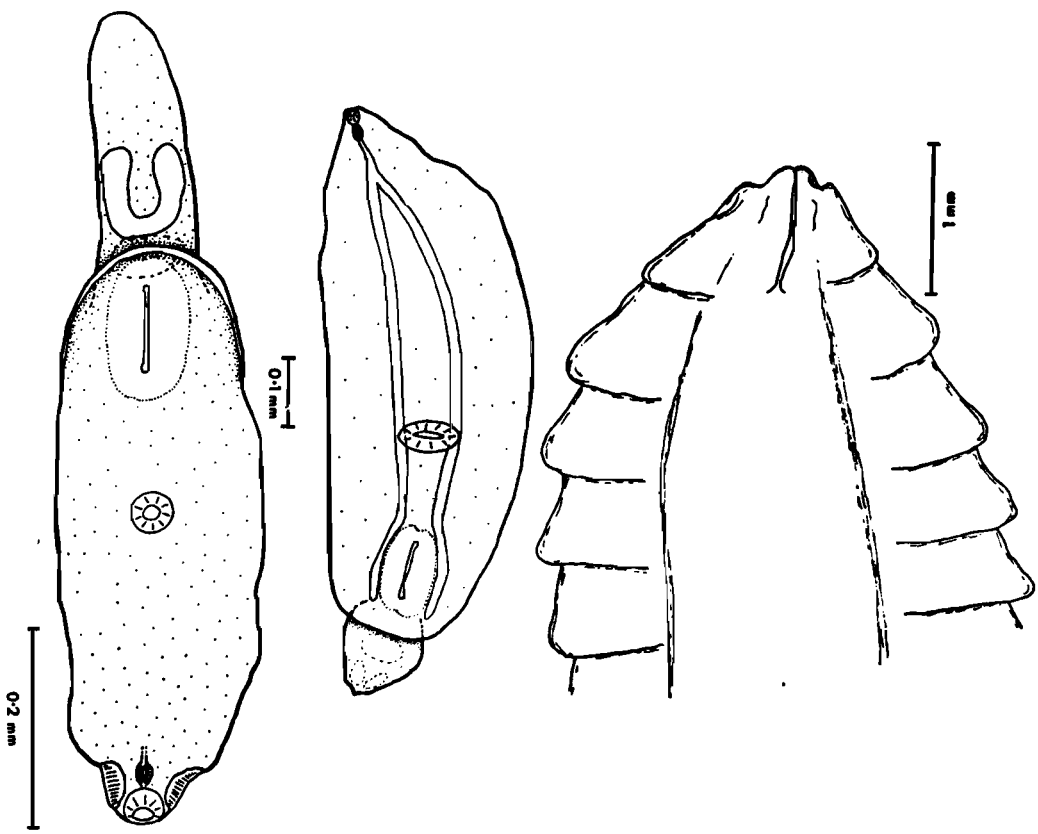


FIGURE 11 (left)
Diplostomum type II. Metacercaria from cranial cavity (ventral view).

FIGURE 12 (centre)
Neodiplostomum metacercaria (ventral view).

FIGURE 13 (right)
Ligula intestinalis. Anterior region.

0,1 mm. The ratio of the length of the hindbody to the forebody varies from 1:2 to 1:3.

Many refractive granules lie within the body and these, together with a wrinkling of the surface, make it difficult to determine the internal structure of the worm. The cuticle does not appear to possess any spines.

The oral sucker is terminal or immediately subterminal. It is rounded and cup-like with a diameter of 40–50 μm. The ventral sucker is also rounded, or transversely oval, and measures about 50 × 45 μm. It lies just posteriorly to the middle of the forebody, at a distance of 0,29–0,32 mm from the anterior end. The oral/ventral sucker ratio is approximately 1:1. Two pseudosuckers, each a concave glandular structure about 55 μm in diameter, occupy the lateral borders of the forebody adjacent to the oral sucker.

The tribocytic organ is oval and measures up to 0,125 × 0,07 mm. It lies in the posterior region of the forebody, close to its junction with the hindbody, and is withdrawn through a median longitudinal slit, 60–70 μm in length. The forebody appears to have a concave ventral surface, which is most evident at its posterior end, where the body tends to become somewhat boat-shaped.

Details of the gut are not clearly visible, but there appears to be a pharynx that measures about 25 × 20 μm and is situated close behind the oral sucker.

The only reproductive organs apparent at this stage of development are the testes. The anterior testis is a transversely-oval body lying just behind the junction of the forebody and the hindbody. The posterior testis is horsehoe-shaped with stout arms directed posteriorly. Both testes lie in the anterior half of the hindbody.

These diplostomula or metacercariae were at first thought to belong to *Diplostomum mashonense* Beverley-Burton, 1963 (a synonym of *D. tregenna* according to Dubois (1970)), from *Clarias mossambicus* in Rhodesia, but the constriction between the forebody and the hindbody is so distinct that a reservation is now held as to the identity of the present form with this species. Moreover, the ventral sucker of *D. mashonense* is distinctly smaller than the oral sucker. Finally, a further diplostomulum or metacercaria, *Monocerca heterobranchi* Wedl, 1861, has been found in the cranial cavity of the Nile catfish, *Heterobranchus anguillaris* [= *Clarias lazera*] and bears a close resemblance to the present form, but again lacks a distinct constriction into a forebody and a hindbody.

The *Neodiplostomum*-type (Figure 12) from the mesenteric tissues, varies from 0,08 to 1,22 mm in length and is divided into a relatively large, dorso-ventrally flattened forebody, and a much smaller, sub-cylindrical hindbody reaching to about one-sixth of the length of the forebody, which is elongate oval. The oral sucker is subterminal, rounded or elongate, and measures 45–50 μm long and 30–50 μm wide. The ventral sucker is transversely oval and measures 67–75 × 87–100 μm and lies close behind the middle of the forebody. The oral/ventral sucker ratio varies from 1:2,3 to 1:2,6. In the caudal region of the forebody an oval tribocytic organ is situated. It measures 0,12–0,16 mm long and 0,1–0,12 mm wide and lies between the ends of the intestinal caeca. Immediately following the oral sucker there is an oval pharynx that measures 37 × 30 μm. The intestine bifurcates at about 30 μm behind the pharynx, and the intestinal caeca extend to the hinder level of the tribocytic organ, but in some specimens the caeca extend well into the hindbody.

Unfortunately, it is not yet possible to recognize the adult form of this larva, but it

probably occurs in a fish-eating bird or mammal, or in a crocodile. It may, however, be noted that the great difference in the sizes of the suckers, as encountered in the present specimens, is often found in the species of *Neodiplostomum* occurring as adults in falconiform and strigiform birds.

CESTODA

Family **Diphyllobothriidae**

Ligula intestinalis (Linn., 1758) Gmelin, 1790

(Figure 13)

This tapeworm was found in the intestine of *Phalacrocorax africanus* from the vicinity of the Low Veldt Fisheries Research Station near Marble Hall, on 24 June 1970. The single specimen available is fragmentary, but appears to represent a complete and mature worm, and together the fragments amount to a length of 214 mm. External segmentation is apparent only in the anterior region of the strobila, while the remainder of the body is smooth or transversely wrinkled.

Modern determinations of *L. intestinalis* appear to have been based principally on the description of this species given by Cooper (1919), but this description was concerned only with European and North American specimens. The presence of *Ligula intestinalis* in Africa was first recognized by Baer (1933) from *Phalacrocorax africanus* in Moçambique, and he described material which differed from that of Cooper in a number of morphological details. Joyeux & Baer (1942), on the other hand, decided that these differences were only of sufficient importance to recognize a variety, which they called *Ligula intestinalis* var. *africana*. Subsequently, Fuhrmann (1943) recorded *L. intestinalis* var. *africana* from *Phalacrocorax africanus* in Angola, and Mahon (1954) recorded *L. intestinalis* doutbfully from the green pigeon, *Treron calva*, in Zaire.

A comparison of European material of *L. intestinalis* from the razorbill, *Alca torda*, with the present specimen, shows a difference in the width of the eggs *in utero*, for in the former material they measure 60–64 × 40–44 μm, whilst in the latter they are 60–64 × 44–48 μm, and the difference in width is exceedingly constant. On present evidence therefore it would seem that *L. intestinalis* var. *africana* might be specifically distinct from the typical *L. intestinalis*, but it is necessary to make a detailed morphological comparison between the European and African specimens before specific or subspecific separation of the two forms could be justified, since varietal units are not recognized as taxa by the International Code on Zoological Nomenclature.

In Europe, the third-larval stage or plerocercoid of *L. intestinalis* occurs in the abdominal cavity of many species of freshwater fishes, more especially cyprinids, and particularly the roach *Rutilus rutilus* in England, but in North America the plerocercoid also develops in a great variety of freshwater fishes. In Africa, the plerocercoid of *L. intestinalis* has been

recorded from various species of *Barbus* in Rhodesia (Mettrick 1960) and Zaire (Mahon 1954), and the present writers have seen plerocercoids of *Ligula* from several kinds of freshwater fishes in the East African lakes and Ethiopia.

In the life-history of this parasite the first intermediate host is a copepod, from which the procercoid larva is released when the host is swallowed by a suitable fish. This larva burrows through the gut-wall of the latter host and settles in the body-cavity. In this situation the larva develops rudimentary reproductive organs and may reach a length of 250–310 mm, but one North American specimen recorded by Cooper (1919) from *Catostomus* measured about 430 mm in length. On entering the gut of the avian final host, the plerocercoid becomes a sexually mature worm within four days, and by the twelfth day has completed its life-history, when the strobila breaks up and is evacuated along with faeces of the host. For a certain period following the loss of the worm the bird is resistant to further infestation, but later it becomes susceptible again.

Fishes infested with the plerocercoids of *Ligula intestinalis* sometimes appear incapable of reproducing. It is probable that the fish becomes infested in the early stages of its development, when feeding on microcrustaceans, and the growth of its reproductive organs is stifled by the constant pressure exerted by the growing larvae, of which more than one is often present. It might also be suggested that the plerocercoid produces a substance that inhibits the growth of the reproductive organs, but it seems more likely that the inhibition is due to a mechanical factor rather than a chemical one.

Family **Dilepididae**

Paradilepis delachauxi (Fuhrmann, 1909)

(Figures 14–16)

Specimens of this species were obtained from the intestine of *Phalacrocorax africanus* at Marble Hall. As is so often the case, the anterior end of the worm is embedded in the intestinal wall of the host. It seems that the scolex burrows through the mucous and submucous membranes to become enclosed in a cavity in the serous coat. The following description is based both on material preserved in spirit, and on microscopical preparations of whole mounts stained with Mayer's paracarmine. Further specimens were examined, from the same host-species taken in Kenya, in order to prepare a description of the scolex and rostellar hooks.

The longest specimen examined was about 113 mm in length and had over 500 segments. The maximum width attained was about 2 mm in a contracted specimen. Nevertheless, in specimens which had been flattened under a cover-glass, the width reached 2,6 mm. At the point where the worm penetrates the intestinal wall of the host, the body (*i.e.* neck) is often constricted to a diameter of 0,4 to 0,5 mm.

The scolex is somewhat globular, with a diameter of 0,6 mm. There is no clear demarcation between the scolex and the neck, as their diameters are rather similar. The scolex bears four nearly spherical suckers, each with a diameter of between 0,16 and 0,175 mm. The

suckers are spaced evenly around the lateral margin of the scolex. At the apex of the scolex there is a rostellum with a diameter of 0,28 mm when invaginated. The rostellum bears a double crown of 20 hooks. There appears to be no description in the literature of a rostellum of this species in the everted state, and it is possible that the hooks are only employed for the purpose of excavating a passage into the intestinal wall, and adhesion is achieved by the use of the suckers alone in the cavity in the intestinal wall. The hooks are characterized by a curved blade and a long handle with a stout guard. Further, there are knobbed structures, 15 to 20 μm in diameter, situated at the base of the handle and of the guard of each hook. The hooks are of two sizes; ten have a length of 115 μm, whilst the other ten are 85 μm long. These measurements do not include terminal knobs. The larger hooks represent the anterior

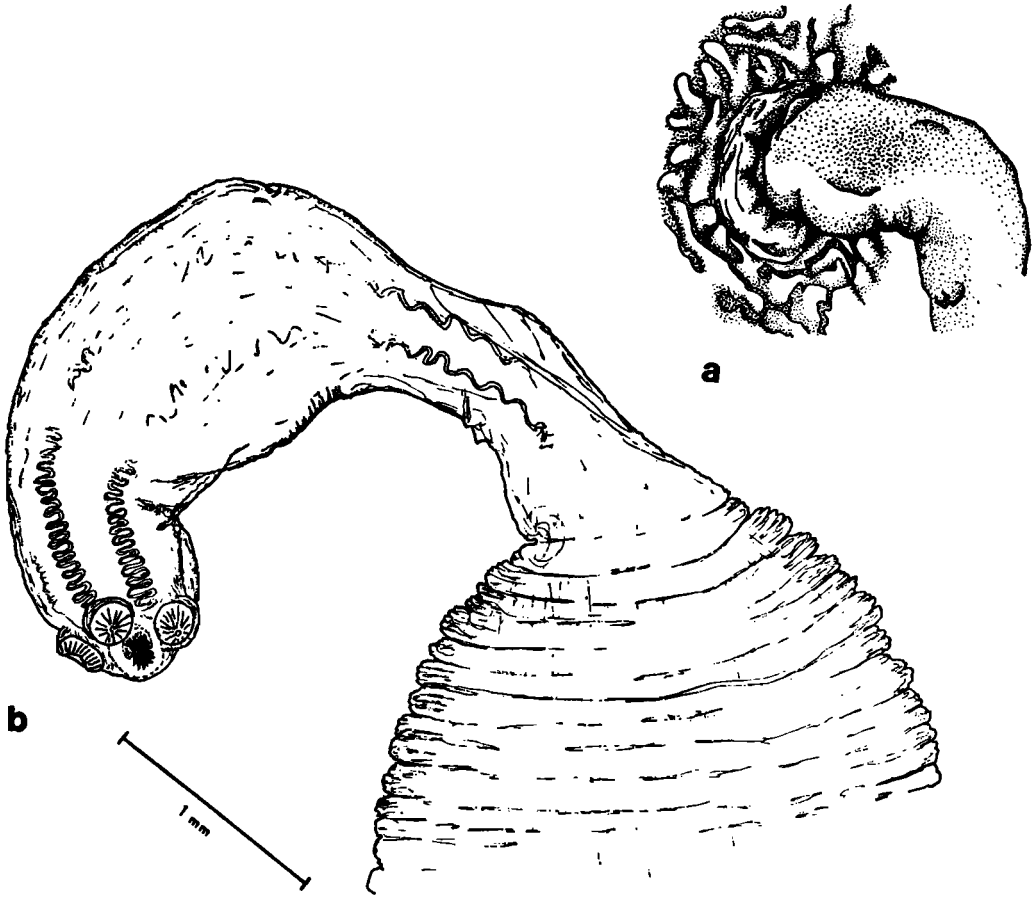


FIGURE 14

Paradilepis delachauxi. (a) attachment of worm to intestinal wall (free-hand sketch by Miss J. S. Williams); (b) anterior end detached from intestinal wall.

crown when the rostellum is protracted.

The segments of the body gradually lengthen as they mature. Early segments, in which the genital primordia are developing, have a ratio of length to width of about 1:10. Mature segments of the stage depicted (Figure 15b) are about 0,28 mm long with a width of 1,3 mm, giving a length to width ratio of about 1:4,5, and when the segments are gravid this ratio has decreased to about 1,3.

On each side of the strobila, the ventral and dorsal excretory canals lie one above the other at about one-fifth of the body-width in from the lateral margins of the worm. The ventral canals are 30 to 40 μm wide and the dorsal canals only 12 to 15 μm.

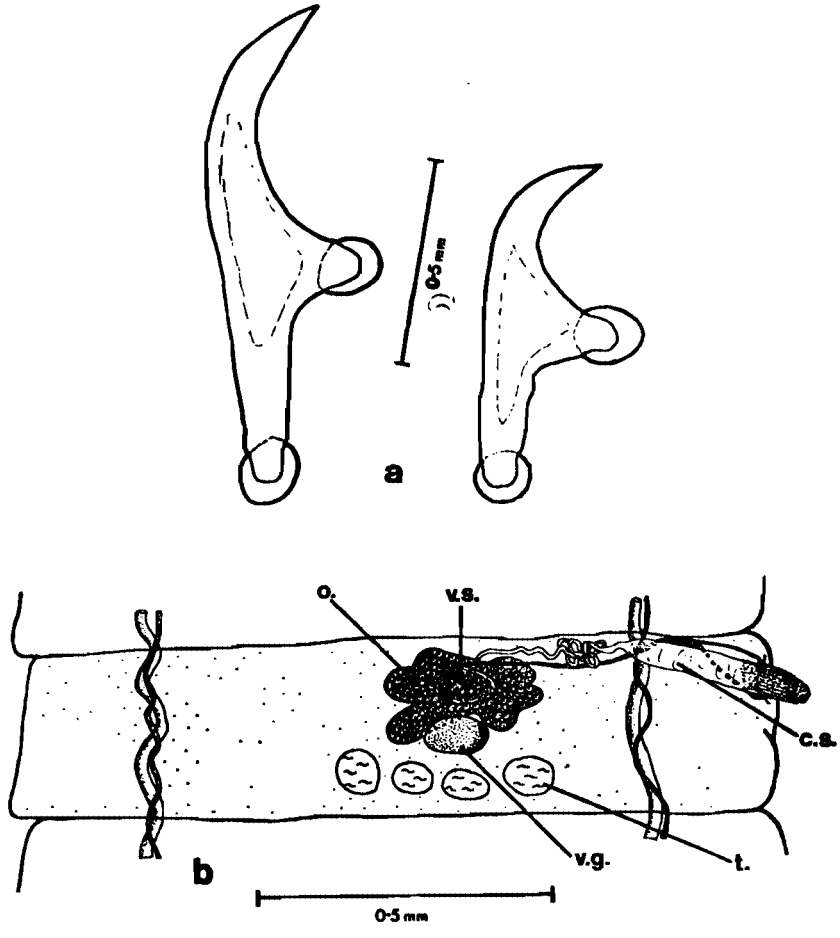


FIGURE 15

Paradilepis delachauxi. (a) examples of large and small rostellar hooks; (b) mature segment (dorsal view). *c.s.*, cirrus-sac; *o.*, ovary; *r.s.*, receptaculum seminis; *t.*, testis; *v.g.*, vitelline gland.

The gonads are situated somewhat asymmetrically, inasmuch as they lie more or less in the poral half of the segment. The earliest of the reproductive organs to appear are the rudiments of the cirrus-sac and the genital ducts, followed by the appearance of the testes.

There are four testes in each segment, but very occasionally a fifth one is present. They are disposed posteriorly in the segment, more or less regularly in a straight line running transversely across the body. They are oval or rounded, but their position, size and shape are somewhat variable. The size-ranges are 62 to 80 μm long and 68 to 80 μm wide. The cirrus and cirrus-sac are conspicuous. The sac lies near the anterior margin of the segment and opens laterally and slightly ventrally. The cirrus-sac is conical, about 0,27 mm long, with a diameter of 50 μm. In most segments the cirrus is protruded from the sac and may extend to a length of 0,215 mm. It is stout and is armed with many rows of minute spines measuring under 5 μm long. The vas deferens leaves the proximal end of the cirrus-sac and passes just inside the anterior margin of the segment to the mid-line before descending towards the testes. Shortly after it leaves the cirrus-sac, the vas deferens becomes convoluted and thrown into compact coils for a short distance, after which it follows an almost straight course. The genital ducts pass dorsally to the excretory canals.

The ovary lies in the anterior half of the segment. Its shape is variable and alters considerably through the course of its development. When fully mature, it is inclined to be a four- or five-lobed organ, which may, however, become somewhat amorphous, on the other

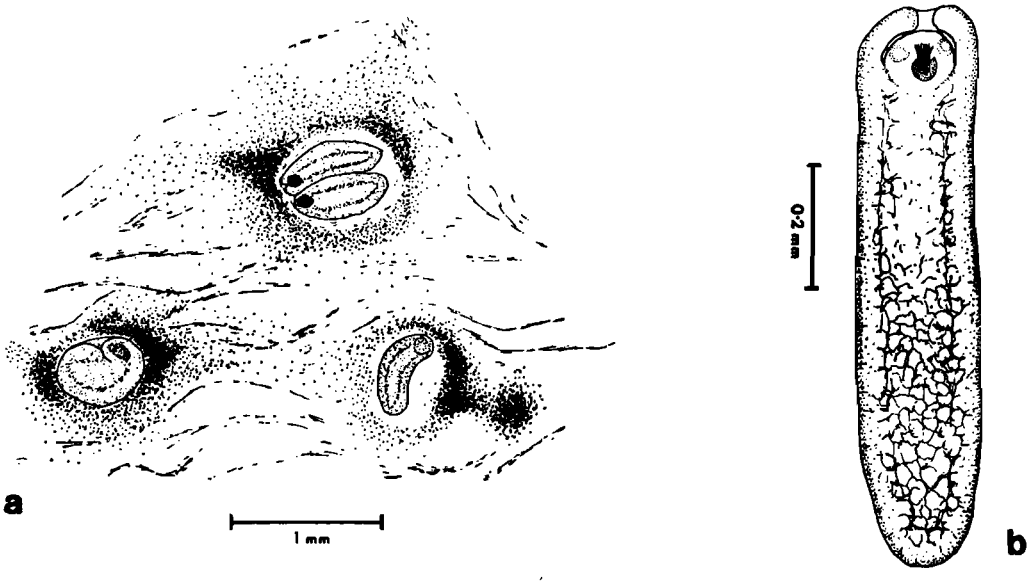


FIGURE 16

Paradilepis sp. (cysticercoids). (a) larvae encysted in intestinal wall of *Tilapia* from Sudan; (b) larva.

hand the lobes themselves may become deeply indented. The ovary in the segment illustrated has dimensions of about 0,18 × 0,24 mm. There is a compact, transversely-oval vitelline gland lying behind the middle of the ovary. It is up to 65 μm long and 90 μm wide. In some specimens this organ may also be lobed. Dorsal to the anterior region of the ovary there is a seminal reservoir. It is the same shape and size as the vitelline gland. A narrow thick-walled vagina emerges from the anterior margin of the seminal reservoir and follows the course of the vas deferens towards the cirrus-sac.

The uterus could not be clearly seen during the early stages of its development, but it eventually becomes visible as a lobed, transversely-elongate, organ situated dorsally to the ovary in the middle of the segment. As the segments become gravid, the uterus gradually fills the whole segment, the lobes becoming larger and larger until the uterus becomes a single sac. The transition between lobed and saccular condition may be quite rapid. The uterus is filled with oval eggs which, in the most mature segments, enclose an embryo with the embryonic hooks already developed. The size of the eggs is about 32 × 25 μm. Generally, the uterus is confined to the area between the two pairs of excretory canals, but in the fully gravid condition the uterus extends laterally beyond the canals.

Although the life-history of *Paradilepis delachauxi* is not yet known with any degree of certainty, the larval stages of an African species of this genus appear as cysticercoids encysted in the intestinal wall of *Tilapia nilotica* in the Sudan, as shown in Figure 16.

NEMATODA

Family **Anisakidae**

Genus *Contracaecum* Railliet & Henry, 1912.

Larvae of this genus were recovered from the bile-ducts, or from cysts in the mesenteries and body-wall, of *Clarias gariepinus* in the Oliphants River during September to January: at Kareepan, Wolmaranstad, Transvaal, in November; and at Malkerns, Swaziland, in March.

Three species of *Contracaecum* commonly occur as adult worms in the oesophagus of African fish-eating birds, and include *C. micropapillatum* (Stossich) usually in cormorants and pelicans, *C. microcephalum* (Rudolphi) and *C. spiculigerum* (Rud.) usually in cormorants, pelicans and herons.

It is most probable that the larvae of other genera of anisakid nematodes occur among the tissues of African freshwater fishes. But on existing knowledge the generic determination of these larvae is exceedingly unlikely. In *Contracaecum*, however, the generic features of the alimentary system, namely, the intestinal caecum and the posterior appendix to the ventriculus, are apparent in the early stages of larval development, sometimes even appearing in the first-stage larva in a copepod. In the larvae of other anisakid genera the modification of the alimentary system seldom appears before the larva has undergone its third moult and reached a length of 20 mm or more.

Contracaecum larvae are exceedingly common in African freshwater fishes, but un-

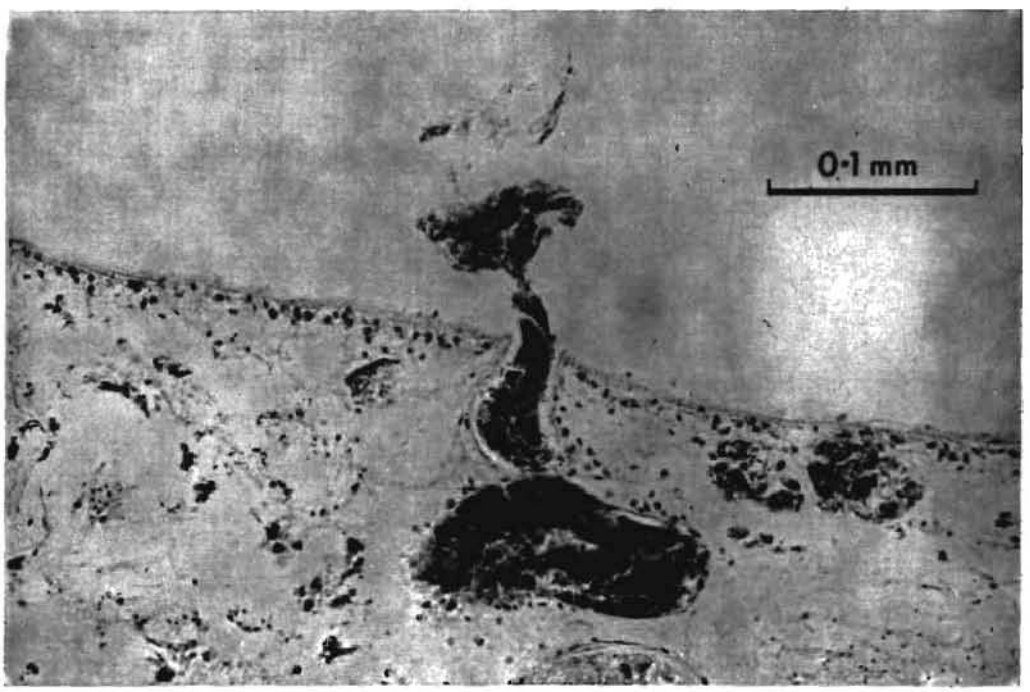


FIGURE 17

Discharge of waste reproductive material through Laurer's canal in *Apharyngostrigea cornu*.

fortunately it seems that none of the diagnostic features of the adults develops until after the worm has undergone its last moult in the final host, and at the moment it is not possible to determine such larvae specifically.

The nematodes in cormorants mentioned by Pott (1972) are likely to have belonged to the genus *Contracaecum*. His statement that adult nematodes may be transferred from the gut of a parent cormorant to its offspring is no doubt justifiable, but he could be misunderstood in suggesting that "If this is the case, the generally complicated cycle that most parasites have to go through, involving different hosts for different stages, would be avoided and infestation would be a direct one from parent to offspring." The fact is that the life-history of all species of *Contracaecum* infesting piscivorous birds requires an alternation of hosts. Briefly, the first-stage larva develops in a microcrustacean, the second and third stages in a fish, and finally the worm undergoes its fourth and last moult in the gut of a suitable bird, and there develops to maturity. This means that the first three moults in the development of the worm must occur outside the final host, and therefore the parent bird merely transfers some of its worms to its offspring, but each worm would have been involved in an indirect life-history.

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