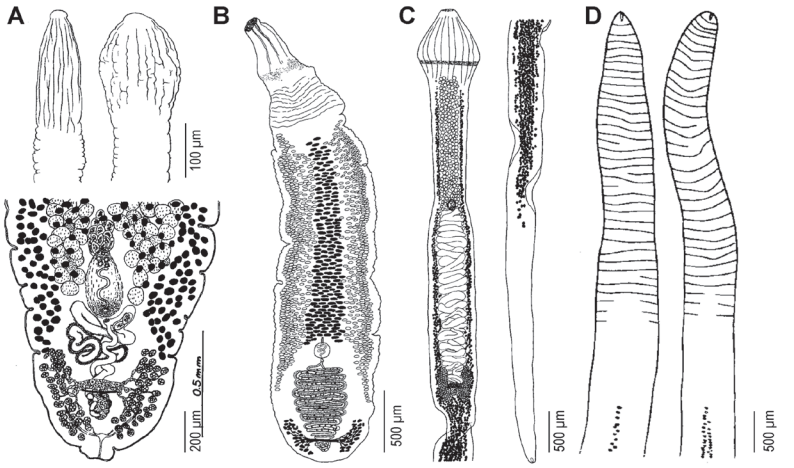

Fig. 4.6.5. Cestoda (Caryophyllidea and Diphyllobothriidea). **A.** *Monobothrioides cunningtoni* Fuhrmann et Baer, 1925 from *Auchenoglanis occidentalis* (scoleces) and *M. woodlandi* Mackiewicz et Beverley-Burton, 1967 from *Clarias ngamensis*; **B.** *Stocksia pujehuni* Woodland, 1937 from *Clarias gariepinus*; **C.** *Wenyonia virilis* Woodland, 1923 from *Synodontis schall*; **D.** *Ligula intestinalis* (Linnaeus, 1758) (plerocercoids) from *Cyprinus carpio*. (Modified from Woodland 1937; Mackiewicz & Beverley-Burton 1967; Dubinina 1980; Schaeffner *et al.* 2011.)

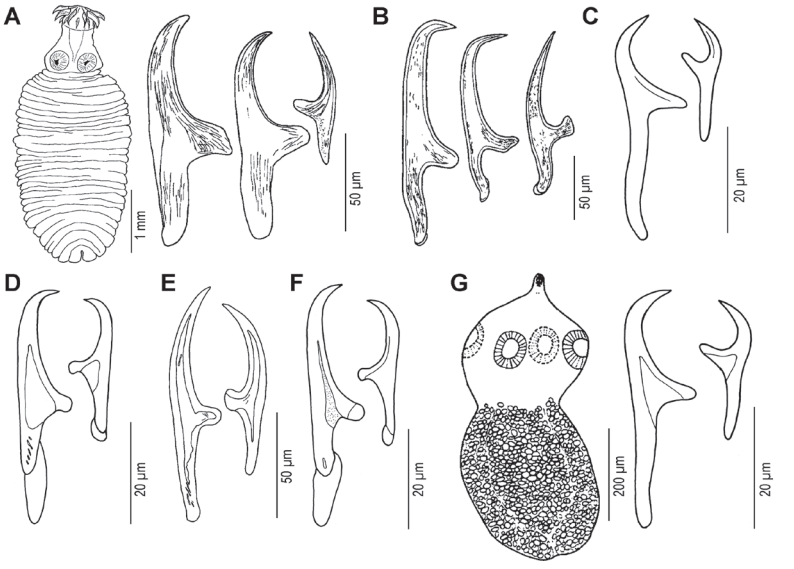

Fig. 4.6.6. Cestoda (Gryporhynchidae – larvae). **A.** *Amirthalingamia macracantha* (Joyeux et Baer, 1935) from *Coptodon zillii*; **B.** *Cyclustera magna* (Baer, 1959) from *C. zillii*; **C.** *Dendrouterina herodiae* Fuhrmann, 1912 from *Schilbe intermedius*; **D.** *Neogryporhynchus lasiopeius* Baer et Bona, 1960 from *Pseudocrenilabrus philander*; **E.** *Paradilepis scolecina* Hsü, 1935 from *P. philander*; **F.** *Parvitaenia samfyia* Mettrick, 1967 from *Tilapia sp.* **G.** *Valipora campylancristrota* (Wedl, 1855) from *Tinca tinca* (total view) and *V. minuta* (Coil, 1950) from *P. philander.* (Modified from Bray 1974; Scholz 1989; Scholz *et al.* 2004, 2018.)

Species are listed alphabetically according to individual cestode orders. Keys to individual cestode orders, their families and genera were provided by Khalil *et al.* (1994). Kuchta *et al.* (2008) split the order Pseudophyllidea Van Beneden in Carus, 1863 into the Bothriocephalidea and Diphyllobothriidea; members of both orders parasitise teleost fishes, but those of the latter order only as larvae (plerocercoids). The type species of each genus and the type host of each species are highlighted in bold. The country where the type locality occurs is given if known. Host names are according to Froese & Pauly (2017).

AMPHILINIDEA Poche, 1922

List of the Amphilinidea (adults) from African freshwater fishes

Nesolecithus Poche, 1922

Nesolecithus africanus Dönges et Harder, 1966 from ***Gymnarchus niloticus*** (Nigeria) [Fig. 4.6.2A]

BOTHRIOCEPHALIDEA Kuchta, Scholz, Brabec et Bray, 2008

Key to the genera of the Bothriocephalidea (adults) from African freshwater fishes (for keys to the species – see Kuchta *et al.* 2012)

1 (2) Apical part of scolex unarmed (without hooks) [Figs 4.6.2B, C; 4.6.3A]……3

2 (1) Apical part of scolex armed (with hooks) [Figs 4.6.2D, E; 4.6.3B]……7

3 (4) Proglottids well demarcated from each other; scolex with well-developed bothria……4

4 (3) Proglottids without obvious demarcation; scolex with weakly developed bothria [Fig. 4.6.2C]……..***Ichthybothrium***

5 (6) Scolex heart-shaped, with deep, sucker-like bothria [Fig. 4.6.3A]…… ……***Schyzocotyle***

6 (5) Scolex elongate to lanceolate, with shallow bothria [Fig. 4.6.2B]…… ……..***Bothriocephalus***

7 (8) Scolex small (< 650 µm); vitelline follicles medullary; testes few (5-20); eggs with transparent, hyaline outer envelope [Fig. 4.6.3B]…… ……***Tetracampos***

8 (7) Scolex large (> 700 µm); vitelline follicles cortical, numerous; testes numerous (> 30, usually more than 100); eggs with hard shell capsule……9

9 (10) Apical disc prominent, wider than scolex, armed with < 36 large, massive hooks, up to 190 µm long; cirrus-sac small, its width representing 5-10% of proglottid width [Fig. 4.6.2E]……..***Polyonchobothrium***

10 (9) Apical disc weakly developed, as wide as scolex or narrower, armed with > 40 hooks shorter than 90 µm; cirrus-sac large, its width representing 16-39% of proglottid width [Fig. 4.6.2D]……..***Kirstenella***

List of the Bothriocephalidea (adults) from African freshwater fishes

Bothriocephalus Rudolphi, 1808

Bothriocephalus claviceps (Goeze, 1782) from ***Anguilla anguilla*** [Fig. 4.6.2B]

Bothriocephalus sp. from *Tilapia* sp.

Ichthybothrium Khalil, 1971

Ichthybothrium ichthybori Khalil, 1971 from ***Ichthyborus besse*** (Sudan), *I. quadrilineatus* [Fig. 4.6.2C]

Ichthybothrium sp. from *Mesoborus crocodilus* [Fig. 4.1F]

Kirstenella Kuchta in Kuchta *et al.* 2012

Kirstenella gordoni (Woodland, 1937) [syn. *Bothriocephalus prudhoei* Tadros, 1966] from ***Heterobranchus bidorsalis*** (Sierra Leone); accidental hosts: *Clarias anguillaris*, *Schilbe mystus* [Fig. 4.6.2D]

Polyonchobothrium Diesing, 1854

Polyonchobothrium polypteri (Leydig, 1853) [syns *Tetrabothrium polypteri* Leydig, 1853; *Onchobothrium septicolle* Diesing, 1854; *Polyonchobothrium septicolle* Diesing 1863; *Anchistrocephalus polypteri* Monticelli, 1900; *Rhynchobothrium polypteri* Klaptocz, 1906; *Polyonchobothrium pseudopolypteri* Meggitt, 1930] from ***Polypterus bichir*** (Egypt), *P. endlicheri*, *P. senegalus* [Fig. 4.6.2E]

Schyzocotyle Akhmerov, 1960

Schyzocotyle acheilognathi (Yamaguti, 1934) [syns *Bothriocephalus acheilognathi* Yamaguti, 1934; *Bothriocephalus* (*Clestobothrium*) *kivuensis* Baer et Fain, 1958; *Bothriocephalus aegyptiacus* Ryšavý et Moravec, 1975; *Bothriocephalus barbus* Fahmy, Mandour et El-Naffar, 1978] from *Carasobarbus fritchii*, *Cyprinus carpio*, *Enteromius annectens*, *E. argenteus*, *E. bifrenatus*, *E. brevipinnis*, *E. mattozi*, *E. paludinosus*, *E. trimaculatus*, *Hydrocynus vittatus*, *Labeobarbus aeneus*, *L. altianalis*, *Labeobarbus bynni*, *L. kimberleyensis*, *L. marequensis*, *L. nedgia*, *Luciobarbus callensis*, *Ptychochromis* cf. *inornatus* [Fig. 4.6.3A]. Records from *Clarias gariepinus*, *Clarotes laticeps*, *Oreochromis mossambicus* and *O. niloticus* need verification.

Tetracampos Wedl, 1861

Tetracampos ciliotheca Wedl, 1861 [syns *Clestobothrium clarias* Woodland, 1925; *Polyonchobothrium cylindraceum* forma *major* Janicki, 1926; *P. cylindraceum* forma *minor* Janicki, 1926; *Polyonchobothrium fulgidum* Meggitt, 1930; *Polyonchobothrium clarias* (Woodland, 1925) Meggitt, 1930; *Polyonchobothrium ciliotheca* (Wedl, 1861) Dollfus, 1934; *Polyoncobothrium ciliotheca* (Wedl, 1861) Yamaguti, 1959; *Polyoncobothrium clarias* (Woodland, 1925) Yamaguti, 1959] from ***Clarias anguillaris*** (Egypt), *C. gariepinus*, *C. liocephalus*, *C. werneri* [Fig. 4.6.3B]

CARYOPHYLLIDEA van Beneden in Carus, 1863

Key to the genera of the Caryophyllidea (adults) from African freshwater fishes

1 (2) Postovarian vitelline follicles present [Figs 4.6.3C-F, 4.6.5C]……3

2 (1) Postovarian vitelline follicles absent [Fig. 4.6.5A, B]……7

3 (4) Body with tail-like posterior part; genital pores in anterior half of the body; in mochokid catfishes (*Synodontis*) [Fig. 4.6.5C]……..***Wenyonia***

4 (3) Body without tail-like posterior part; genital pores near the posterior end of the body……5

5 (6) Vitelline follicles present alongside lateral ovarian lobes; in carp (introduced) [Fig. 4.6.3C]……***Atractolytocestus***

6 (5) Vitelline follicles absent alongside lateral ovarian lobes; in barbels [Fig. 4.6.3E]……..***Khawia***

7 (8) Vitelline follicles absent medially; in *Clarias* [Fig. 4.6.5B]……***Stocksia***

8 (7) Vitelline follicles present also medially (on ventral and dorsal side of cortex) ……9

9 (10) Body small (maximum length 11 mm), tapering slightly from conical scolex with longitudinal wrinkles; vitelline follicles extensive, filling most of cortex throughout body; in cichlids [Fig. 4.6.3D]……***Lytocestoides***

10 (9) Body larger, of different shapes; vitelline follicles less extensive……11

11 (12) Scolex with longitudinal wrinkles; in *Auchenoglanis* and *Clarias* [Fig. 4.6.5A]……***Monobothrioides***

12 (12) Scolex elongate, simple, without longitudinal wrinkles; in Alestidae, Mormyridae and *Clarias* [Fig. 4.6.3F]……...***Lytocestus***

List of the Caryophyllidea (adults) from African freshwater fishes

Atractolytocestus Anthony, 1958

Atractolytocestus huronensis Anthony, 1958 from ***Cyprinus carpio*** [introduced with common carp] [Fig. 4.6.3C]

Khawia Hsü, 1935

Khawia armeniaca (Cholodkovsky, 1915) from *Labeobarbus bynni*, *L. callensis*, *L. tropidolepis*, *L. setivimensis* [reported as *Caryophyllaeus laticeps* (Pallas, 1781)] [Fig. 4.6.3E]

Khawia sp. from *Labeobarbus bynni*

Lytocestus Cohn, 1908

Lytocestus filiformis (Woodland, 1923) from ***Mormyrus caschive*** (Sudan), *Mormyrus* sp.

Lytocestus marcuseni Troncy, 1978 [syn. *L. alestesi* Lynsdale, 1956] from *Brycinus nurse*, ***Hippopotamyrus harringtoni*** (Chad) [Fig. 4.6.3F]

Lytocestus puylaerti Khalil, 1973 from ***Clarias buettikoferi*** (Sierra Leone)

Lytocestus sp. from *Auchenoglanis occidentalis*

Lytocestoides Baylis, 1928

Lytocestoides tanganyikae Baylis, 1928 from a **cichlid** (Tanzania) [Fig. 4.6.3D]

Lytocestoides sp. from *Parectodus* sp.

Monobothrioides Fuhrmann et Baer, 1925

Monobothrioides chalmersius (Woodland, 1924) from ***Clarias anguillaris*** (Sudan)

Monobothrioides cunningtoni Fuhrmann et Baer, 1925 from ***Auchenoglanis occidentalis*** (Zambia) [Fig. 4.6.5A]

Monobothrioides tchadensis Troncy, 1978 from ***Auchenoglanis biscutatus*** (Chad)

Monobothrioides woodlandi Mackiewicz et Beverley-Burton, 1967 from ***Clarias ngamensis*** (Zambia) [Fig. 4.6.5A]

Monobothrioides sp. from *Parauchenoglanis ballayi*, *Synodontis schall*

Stocksia Woodland, 1937

Stocksia pujehuni Woodland, 1937 from ***Clarias gariepinus*** (Sierra Leone) [Fig. 4.6.5B]

Wenyonia Woodland, 1923 (see Schaeffner *et al.* 2011 for a key to species)

Wenyonia acuminata Woodland, 1923 from *Synodontis acanthomias*, ***S. membranaceus*** (Sudan)

Wenyonia longicauda Woodland, 1937 from **Synodontis gambiensis** (now considered to be a synonym of *S. schall*) (Sierra Leone)

Wenyonia minuta Woodland, 1923 [syn. *Wenyonia mcconnelli* Ukoli, 1972] from *Synodontis caudovittatus*, *S. frontosus*, *S. nigrita*, *S. schall*, *S. serratus*; ***Chrysichthys auratus*** (Sudan) is incidental host

Wenyonia synodontis Ukoli, 1972 from *Synodontis schall*, ***S. sorex*** (Nigeria), *S. vermiculatus*

Wenyonia virilis Woodland, 1923 [syns *Caryophyllaeus niloticus* Kulmatycki, 1928; *Wenyonia kainjii* Ukoli, 1972] from *Synodontis batensoda*, *S. budgetti*, *S. caudovittatus*, *S. clarias*, *S. eupterus*, *S. frontosus*, *S.* cf. *geledensis*, *S. nigrita*, *S. ocellifer*, ***S. schall*** (Sudan), *S. serratus*, *S. sorex* [Fig. 4.6.5C]

Wenyonia youdeoweii Ukoli, 1972 from *Synodontis caudovittatus*, ***S. gobroni*** (Nigeria), *S. schall*, *S. serratus*

Wenyonia sp. from *Synodontis batensoda*

Key to the genera of the Onchoproteocephalidea (only family Proteocephalidae; adults) from African freshwater fishes

1 (2) Vitellarium formed by numerous follicles arranged in paired lateral bands; scolex without a highly modified apical structure with retractile lappets……3

2 (1) Vitellarium formed by two compact, but deeply lobulated, postovarian masses near the posterior margin of proglottids; scolex with a highly modified apical structure formed by four muscular retractile lappets [Fig. 4.6.4F] ……***Sandonella***

3 (4) Scolex umbrella-shaped, with widely pyramidal apex and well-developed metascolex, which forms folded collar surrounding suckers; external margins of suckers with semispherical sphincter; body surface with deep longitudinal and transverse grooves (wrinkles) forming rectangular network; in electric catfish (*Malapterurus*) [Fig. 4.6.4C]……***Corallobothrium***

4 (3) Scolex of different shapes, metascolex absent; sphincter on suckers and longitudinal and transverse grooves on the strobila usually absent……5

5 (6) Scolex with apical rostellum armed with tiny hooks; in electric catfish (*Malapterurus*) [Fig. 4.6.4B]……...***Electrotaenia***

6 (5) Scolex without rostellum, without any hooks; in other fishes……7

7 (8) Tapeworms very large, robust (total length up to 173 mm; maximum width 1.8 mm); scolex round, suckers with muscular sphincter; in clariid catfishes ……..9

8 (7) Tapeworms smaller; scolex often conical; suckers without sphincters [Fig. 4.6.4D]……..***Proteocephalus***

9 (10) Scolex with additional posterior orifices and muscular sphincters; testes medullary [Fig. 4.6.4A]…….***Barsonella***

10 (9) Suckers without additional posterior orifices and muscular sphincters; testes in dorsal cortex [Fig. 4.6.4E]……..***Marsypocephalus***

List of the Onchoproteocephalidea (Proteocephalidae; adults) from African freshwater fishes

Barsonella de Chambrier, Scholz, Beletew et Mariaux, 2009

Barsonella lafoni de Chambrier, Scholz, Beletew et Mariaux, 2009 from ***Clarias gariepinus*** (Ethiopia) [Fig. 4.6.4A]

Corallobothrium Fritsch, 1886

Corallobothrium solidum Fritsch, 1886 from ***Malapterurus electricus*** (Egypt) [Fig. 4.6.4C]

Electrotaenia Nybelin, 1942

Electrotaenia malopteruri (Fritsch, 1886) from ***Malapterurus electricus*** (Egypt) [Fig. 4.6.4B]

Marsypocephalus Wedl, 1861

Marsypocephalus aegyptiacus El-Naffar, Saoud et Hassan, 1984 from ***Clarias gariepinus*** (Egypt)

Marsypocephalus daveyi Woodland, 1937 from ***Heterobranchus bidorsalis*** (Sierra Leone)

Marsypocephalus heterobranchus Woodland, 1925 from ***Heterobranchus bidorsalis*** (Sudan)

Marsypocephalus rectangulus Wedl, 1861 from *Clarias anguillaris*, ***C. gariepinus*** (Egypt), *Heterobranchus bidorsalis*

Marsypocephalus tanganyikae (Fuhrmann et Baer, 1925) from ***Clarias gariepinus*** (Zambia) [Fig. 4.6.4E]

Marsypocephalus sp. from *Heterobranchus bidorsalis*

Proteocephalus Weinland, 1858

Proteocephalus beauchampi Fuhrmann et Baer, 1925 from *Chrysichthys brachynema*, ***Chrysichthys* sp.** (Democratic Republic of the Congo); a record from *Synodontis schall* is doubtful

Proteocephalus bivitellatus Woodland, 1923 from a **carnivorous cichlid** (Sierra Leone)

Proteocephalus cunningtoni Fuhrmann et Baer, 1925 from ***Dinotopterus cunningtoni*** (Zambia)

Proteocephalus dinotopteri Fuhrmann et Baer, 1925 from ***Dinotopterus cunningtoni*** (Zambia)

Proteocephalus glanduligerus Janicki, 1928 from ***Clarias anguillaris*** (Egypt), *C. gariepinus*

Proteocephalus membranacei Troncy, 1978 [syn. *Proteocephalus largoproglottis* Troncy, 1978] from ***Synodontis membranaceus*** (Chad)

Proteocephalus pentastomus (Klaptocz, 1906) from ***Polypterus bichir*** (Sudan), *P. endlicheri*, *P. senegalus*

Proteocephalus sulcatus (Klaptocz, 1906) from ***Clarotes laticeps*** (Sudan); accidental hosts: *Chrysichthys* sp., *Clarias anguillaris*, *C. gariepinus*, *Clarotes laticeps*, *Polypterus endlicheri*

Proteocephalus synodontis Woodland, 1925 from *Auchenoglanis* cf. *occidentalis*, *Synodontis batensoda*, *S. caudovittatus*, *S. eupterus*, *S. frontosus*, *S. nigrita*, ***S. schall*** (Sudan), *S. serratus* [Fig. 4.6.4D]

Proteocephalus sp. from *Ichthyborus besse*

Sandonella Khalil, 1960

Sandonella sandoni (Lynsdale, 1960) from ***Heterotis niloticus*** (Sudan) [Fig. 5.6.4F]

CYCLOPHYLLIDEA van Beneden in Braun, 1900 – family Gryporhynchidae Spassky et Spasskaya, 1973

Key to the larvae (metacestodes) of the family Gryporhynchidae (Cyclophyllidea) from African freshwater fishes

1 (2) Hooks of three shapes (4 + 6 + 10 in number), massive, very large (> 200 µm long)……3

2 (1) Hooks of two different shapes (10 + 10 in number), more delicate, smaller ……...5

3 (4) Hooks > 390 µm (larger) and > 240 µm (smaller) long [Fig. 4.6.6A]…… ……..***Amirthalingamia***

4 (3) Hooks < 200 µm (larger) and < 150 µm (smaller) long [Fig. 4.6.6B] ……***Cyclustera***

5 (6) Large hooks > 90 µm long, massive, with slightly curved blade [Fig. 4.6.6E] ……***Paradilepis***

6 (5) Large hooks < 50 µm long, delicate, with abruptly curved blade……7

7 (8) Hooks tiny, large hooks < 31 µm long; in gall bladder [Fig. 4.6.6G]…… ……..***Valipora***

8 (7) Hooks larger, large hooks > 45 µm long; larvae in other sites of infection……9

9 (10) Blade of larger hooks slightly longer, straighter [Fig. 4.6.6F]…… ……***Parvitaenia***

10 (9) Blade of larger hooks slightly shorter, more curved; hooks 48-50 µm long ……11

11 (12) Hooks more robust, with blade tip of larger hooks directed more anteriorly [Fig. 4.6.6D]……...***Neogryporhynchus***

12 (11) Hooks more slender, with blade tip of larger hooks more curved [Fig. 4.6.5C] ……..***Dendrouterina***

List of the larvae (metacestodes) of the family Gryporhynchidae (Cyclophyllidea) from African freshwater fishes (see Scholz et al. 2018 for a review of African gryporhynchid larvae)

Amirthalingamia Bray, 1974

Amirthalingamia macracantha (Joyeux et Baer, 1935) from *Coptodon zillii*, *Oreochromis niloticus*, *Pharyngochromis acuticeps*, *Pseudocrenilabrus philander*, *Tilapia sparrmanii* [Fig. 4.6.6A]

Anomotaenia Cohn, 1900

Anomotaenia sp. from *Hemichromis fasciatus*, *Oreochromis niloticus*; identification needs verification because the genus belongs to the family Dilepididae and no vouchers were deposited by Aderounmu & Adeniyi (1972).

Cyclustera Fuhrmann, 1901

Cyclustera magna (Baer, 1959) from *Coptodon zillii*, *Labeo horie*, *Oreochromis niloticus*, *Sarotherodon galilaeus* [Fig. 4.6.6B]

Cyclustera sp. from *Cyprinus carpio* – see Scholz *et al.* (2008)

Dendrouterina Fuhrmann, 1912

Dendrouterina herodiae Fuhrmann, 1912 from *Schilbe intermedius* [Fig. 4.6.6C]

Neogryporhynchus Baer et Bona, 1960

Neogryporhynchus lasiopeius Baer et Bona, 1960 from *Bathybathes graueri*, *Chetia flaviventris*, *Coptodon rendalli*, *Cyprinus carpio*, *Heterotis niloticus*, *Oreochromis mossambicus*, *O. niloticus*, *Pseudocrenilabrus philander*, *Tilapia sparrmannii* [Fig. 4.6.6D]

Paradilepis Hsü, 1935

Paradilepis delachauxi (Fuhrmann, 1909) from *Chetia flaviventris*, *Coptodon rendalli*, *Labeobarbus marequensis*, *Oreochromis macrochir*, *Pharyngochromis acuticeps*, *Pseudocrenilabrus philander*

Paradilepis maleki Khalil, 1961 from *Benthochromis horii*, *Pseudocrenilabrus philander*

Paradilepis scolecina Hsü, 1935 from *Coptodon rendalli*, *Enteromius paludinosus*, *E. trimaculatus*, *E. unitaeniatus*, *Labeobarbus kimberleyensis*, *Oreochromis mossambicus*, *Pseudocrenilabrus philander* [Fig. 4.6.6E]

Paradilepis sp. from *Chetia flaviventris*, *Coptodon rendalli*, *Oreochromis mossambicus*, *Pharyngochromis acuticeps*, *Pseudocrenilabrus philander*

Parvitaenia Burt, 1940

Parvitaenia macropeos (Wedl, 1855) from *Coptodon rendalli*, *Hemichromis letourneuxi*, *Oreochromis mossambicus*, *O. niloticus*

Parvitaenia samfyia Metrick, 1967 from *Pseudocrenilabrus philander*, *Tilapia* sp. [Fig. 4.6.6F]

Parvitaenia sp. 1 from *Enteromius treurensis*, *E. trimaculatus*

Parvitaenia sp. 2 from '*Barbus*' sp., *Enteromius macrops*, *E. trimaculatus*

Parvitaenia sp. 3 from *Pseudocrenilabrus philander*

Valipora Linton, 1927

Valipora campylancristrota (Wedl, 1855) from *Enteromius paludinosus*, *Pseudocrenilabrus philander* [Fig. 4.6.5G]

Valipora minuta (Coil, 1950) from *Chetia flaviventris*, *Ophthalmotilapia nasuta*, *Pseudocrenilabrus philander*, *Ptychochromis grandidieri* [Fig. 4.6.5G]

DIPHYLLOBOTHRIIDEA Kuchta, Scholz, Brabec et Bray, 2008

List of the Diphyllobothriidea (larvae) from African freshwater fishes

Ligula Bloch, 1782

Ligula intestinalis (Linnaeus, 1758) (plerocercoids) from *Chagunius nicholsi*, *Enteromius kamolondoensis*, *E. lineomaculatus*, *E. lukusiensis*, *E. paludinosus*, *E. radiatus*, *E. unitaeniatus*, *Haplochromis* sp., *Labeobarbus marequensis*, *L. microbarbis*, *Labeo lukulae*, *Rastrineobola argentea* [Fig. 4.6.5D]

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Chapter 4.7.
ACANTHOCEPHALA

Bernd SURES, Yuriy KVACH & Roman KUCHTA

Thorny-headed worms (Acanthocephala) – basic characteristics, life cycles, classification and principal diagnostic features

- parasitic 'worms' (Syndermata: Rotifera)
- about 1,300 species classified in 4 classes (Archiacanthocephala, Eoacanthocephala, Palaeacanthocephala and Polyacanthocephala) and 10 orders (Amin 2013; Warner 2014), from which 19 species occur in Africa
- heteroxenous parasites, with adults in the intestine of vertebrates (definitive hosts) and larvae (cystacanths) in haemocoel of arthropods (intermediate hosts); paratenic hosts (vertebrates) occur occasionally
- behavioural changes of intermediate hosts induced by acanthocephalan larvae (cystacanths) increase their vulnerability to predation and thus foster transmission rates to the definitive host (Sures 2014)
- body divided into a trunk (metasoma) and anterior tip with proboscis armed with hooks (prosoma)

Most of the inner organs of acanthocephalans are located within the trunk. Acanthocephalans are dioecious. The ovaries (ovarian balls) of female worms float in the body cavity. Following fertilisation of mature eggs the ovary degenerates and the body cavity is filled with developing eggs. As soon as eggs contain fully developed first stage larvae (acanthors) they are released by the female through an apparatus called the uterine bell.

In addition to the testes, male worms have one to eight cement glands whose secretions enable a male to plug the vagina of a female after fertilisation. Acanthocephalans lack an intestinal tract and take up all nutrients through their body wall. In addition to nutrients, acanthocephalans take up and accumulate toxic substances such as metals, which makes them excellent indicators of environmental pollution (Sures *et al.* 2017).

Higher-level classification (families, orders and classes – see Amin 2013) is based on the amount of cement glands, the shape of the eggs, presence/absence of subtegumental giant nuclei and spines on the trunk, size and number of proboscis hooks, structure of the excretory system, etc.

At the genus and species-level, the key morphological structure for identification is the proboscis (shape and size of the proboscis, the number of files of proboscis hooks, the number of hooks in individual files, size, shape and type of proboscis hooks, etc.). Other morphological characteristics used for identification include

the size and structure of the egg containing the fully developed acanthor, the position of the cephalic ganglion, the morphology of the reproductive system, *e.g.*, the shape and supination of the penis (male copulatory organ) and the vulva (in females), the number of giant hypodermal nuclei, the length of lemnisci, the size of males and females, etc.

Fig. 4.7.1. Life cycle of acanthocephalans. *Acanthocephalus lucii* (Müller, 1776); isopods serve as intermediate hosts. (Illustration by M. Luo.)

Key to the classes and orders of acanthocephalans in African fishes

1 (2) Lemnisci, cement gland and hypodermal nuclei fragmented; ligament sacs in females single, not persistent; proboscis receptacle double walled. Parasites of fishes, amphibians, reptiles, birds, and mammals (class **Palaeacanthocephala**)……..5

2 (1) Lemnisci, cement gland and/or hypodermal nuclei not fragmented, usually giant; ligament sacs in females double, persistent; proboscis receptacle single-walled, complex or absent……3

3 (4) Trunk spined; proboscis claviform with numerous longitudinal rows of hooks; cement glands separate, elongate pyriform to tubular; eggs with acanthor oval with radial sculpturings at right angles to surface. Parasites of fishes and Crocodilia (class **Polyacanthocephala**) [Fig. 4.7.2D] ……order **Polyacanthorhynchida**

4 (3) Trunk may be spined; proboscis usually small with few radially arranged hooks; cement gland single, syncytial, additional distinct cement reservoir; eggs with acanthor variably shaped but not like above. Parasites of fishes and occasionally amphibians and reptiles (class **Eoacanthocephala**)…..7

5 (6) Parasites of fishes and amphibians [Figs 4.7.2A–C]…… ……..order **Echinorhynchida**

6 (5) Trunk spinose. Parasites of reptiles (rare), birds and mammals; larvae in fish……order **Polymorphida** [Fig. 4.7.2E]

7 (8) Trunk entirely or only anteriorly spined. Parasites of freshwater and marine fishes [Fig. 4.7.3A,C]…….order **Gyracanthocephala**

8 (9) Trunk unarmed [Fig. 4.7.3B,D,E]……..order **Neoechinorhynchida**

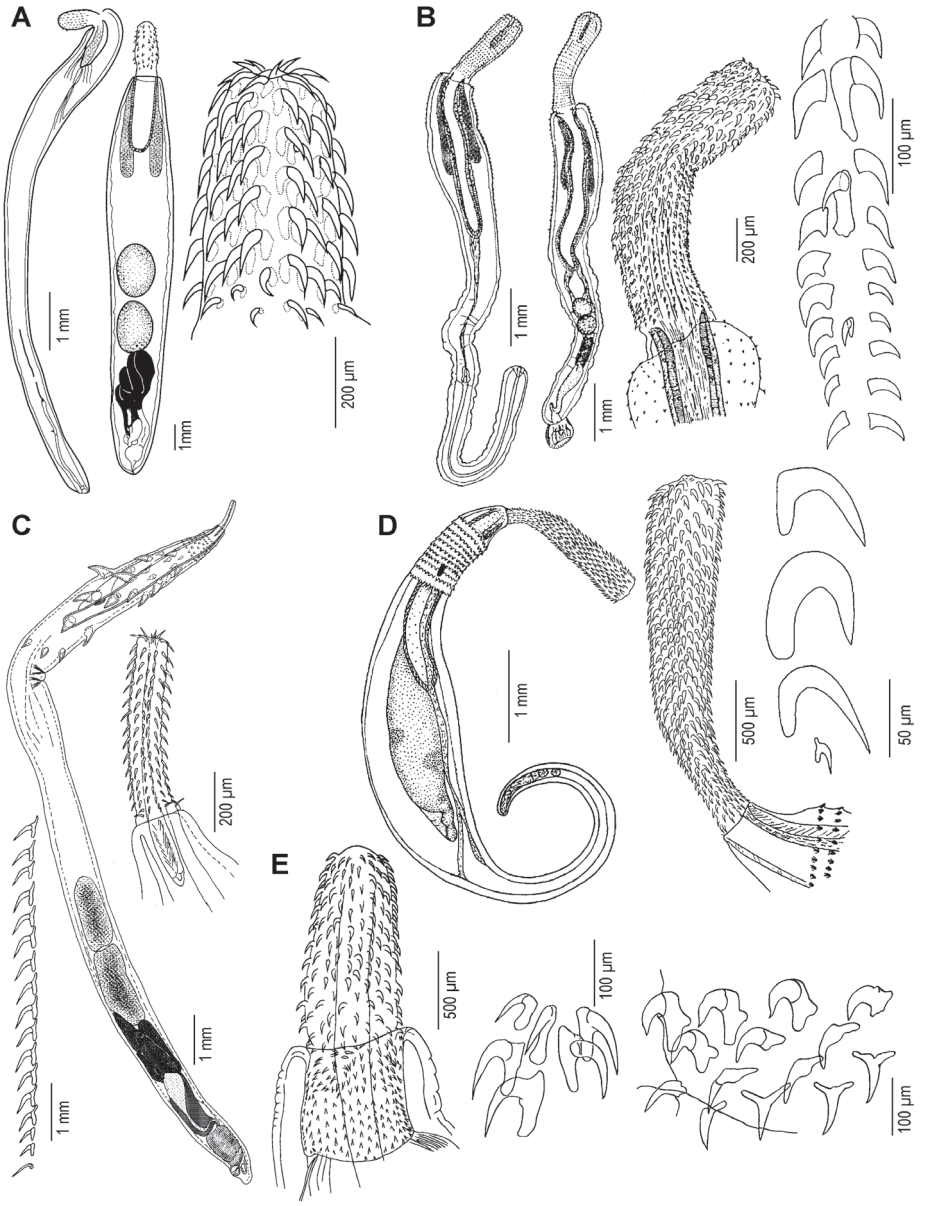

Fig. 4.7.2. Acanthocephala. **A.** *Acanthocephalus lucii* (Müller, 1776) from *Barbus* sp; **B.** *Paragorgorhynchus albertianus* Golvan, 1957 from *Alestes dentex*; **C.** *Megistacantha horridum* (Lühe, 1912) from *Hyperopisus bebe*; **D.** *Polyacanthorhynchus kenyensis* Schmidt et Canaris, 1967 from *Tilapia* sp.; **E.** *Arhythmorhynchus siluricola* Dollfus, 1929 from *Gephyroglanis* sp. (Modified from Dollfus 1929; Petrochenko 1956; Yamaguti 1963; Schmidt & Canaris 1967; Kvach *et al.* 2016.)

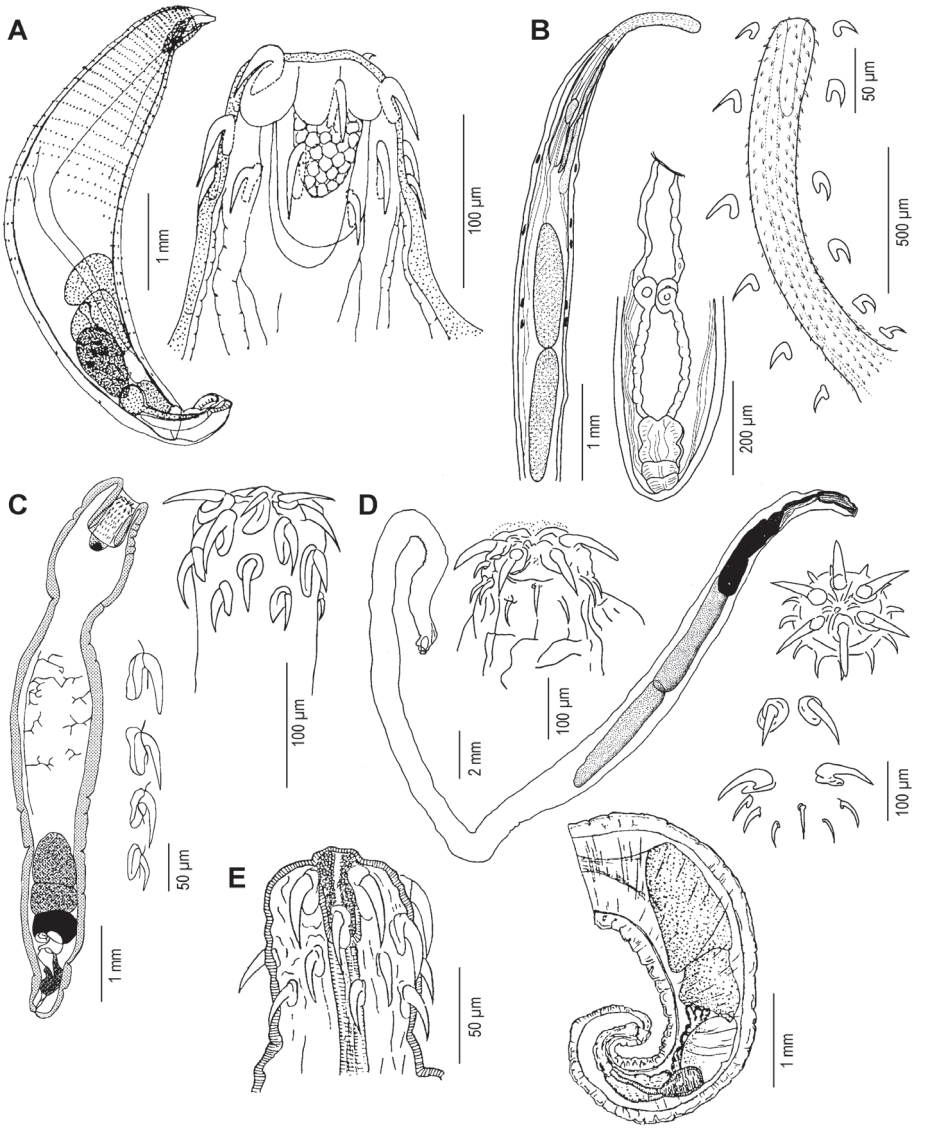

Fig. 4.7.3. Acanthocephala. **A.** *Acanthogyrus malawiensis* Amin et Hendrix, 1999 from *Labeo cylindricus*; **B.** *Tenuisentis niloticus* (Meyer, 1932) from *Heterotis niloticus*; **C.** *Pararaosentis golvani* (Troncy et Vassiliadès, 1973) from *Synodontis batensoda*; **D.** *Neoechinorhynchus africanus* Troncy, 1970 from *Citharinops distichodoides*; **E.** *Hexaspiron nigericum* Dollfus and Golvan, 1956 from *Synodontis membranaceus*. (Modified from Meyer 1932; Dollfus & Golvan 1956; Yamaguti 1963; Troncy 1970; Troncy & Vassiliadès 1973; Amin & Hendrix 1999.)

List of adult spiny-headed worms (Acanthocephala) from African freshwater fishes

Species are listed alphabetically according to individual families; the system of Amin (2013) is followed. No monograph on the Acanthocephala with keys to the families and genera has been published since Petrochenko (1956). Type species and type host species are highlighted in bold. Country of the type locality is given.

Echinorhynchida Petrochenko, 1956

Key to the genera of the Echinorhynchida from African freshwater fishes

1 (2) Trunk unarmed, cylindrical to fusiform; proboscis cylindrical, claviform or spherical, terminal; transition between true proboscis hooks and basal spiniform hooks gradual; neck and proboscis receptacle short; cement glands 6 or 8, usually pyriform to spherical and compact; eggs fusiform or elliptical (family Echinorhynchidae) [Fig. 4.7.2A]…… ***Acanthocephalus***

2 (1) Trunk armed with tegument spines; proboscis subcylindrical; proboscis receptacle long; brain ganglion anterior; cement glands 4-6, elongate and tubular or short and pyriform (family Rhadinorhynchidae)……3

3 (4) Middle-sized worms; trunk armed with tegument spines anteriorly; spines more numerous on the ventral side [Fig. 4.7.2B]……..***Paragorgorhynchus***

4 (3) Body large, 1.5-2 cm in length; trunk covered with giant spines in anterior part. Parasites of mormyrid fish [Fig. 4.7.2C]……***Megistacantha***

List of the Echinorhynchida from African freshwater fishes

Echinorhynchidae Cobbold, 1876

Acanthocephalus Koelreuther, 1771

Acanthocephalus lucii (Müller, 1776) from *Oreochromis niloticus* [Fig. 4.7.2A]

Rhadinorhynchidae Travassos, 1923

Megistacantha Golvan, 1960

Megistacantha horridum (Lühe, 1912) from *Gnathonemus petersii*, *Hyperopisus bebe*, *Hippopotamyrus pictus*, ***Marcusenius cyprinoides*** (Egypt) [Fig. 4.7.2C]

Megistacantha sanghaensis Kvach, Jirků et Scholz, 2016 from ***Mormyrops anguilloides*** (Central African Republic)

Paragorgorhynchus Golvan 1957

Paragorgorhynchus albertianus Golvan, 1957 from *Alestes dentex*, *Bagrus bajad*, *Hydrocynus forskahlii*, ***Lates niloticus*** (Congo), *Schilbe mystus* [Fig. 4.7.2B]

Paragorgorhynchus aswanensis Saoud et Wanas, 1990 from *Bagrus bajad*, *B. docmak*, *Clarias gariepinus*, ***Lates niloticus*** (Egypt), *Tetraodon lineatus*

Paragorgorhynchus chariensis Troncy, 1970 from ***Lates niloticus*** (Chad)

Paragorgorhynchus sp. from *Clarias gariepinus*

Polyacanthorhynchida Amin, 1987

List of the Polyacanthorhynchida from African freshwater fishes

Polyacanthorhynchidae Golvan, 1926

Polyacanthorhynchus Travassos, 1920

Polyacanthorhynchus kenyensis Schmidt et Canaris, 1967 (juvenile) from *Coptodon zillii*, *Enteromius paludinosus*, *Micropterus salmoides*, *Oreochromis leucostictus*, *O. niloticus*, ***Tilapia*** **sp.** (Kenya) [Fig. 4.7.2D]

Polymorphida Petrochenko, 1956

List of the Polymorphida from African freshwater fishes

Polymorphidae Meyer, 1931

Arhythmorhynchus Lühe, 1911

Arhythmorhynchus siluricola Dollfus, 1929 (juvenile) from *Chrysichtys* sp., ***Gephyroglanis*** **sp.** (Cameroon) [Fig. 4.7.2E]

Gyracanthocephala Van Cleave, 1936

Key to the genera of the Gyracanthocephala from African freshwater fishes

1 (2) Trunk armed only anteriorly with circles of spines; circles usually incomplete dorsally (subfamily Quadrigyrinae) [Fig. 4.7.3A]…… ……..***Acanthogyrus***

2 (1) Trunk armed anteriorly with complete circles of spines in one or two regions separated by an unarmed zone; spines in the second region may extend over the rest of the trunk in circles or in longitudinal rows (subfamily Pallisentinae) [Fig. 4.7.3C]…… ***Pararaosentis***

List of the Gyracanthocephala from African freshwater fishes

Quadrigyridae Van Cleave, 1920

Acanthogyrus Thapar, 1927

Acanthogyrus malawiensis Amin et Hendrix, 1999 from ***Labeo cylindricus*** (Malawi) [Fig. 4.7.3A]

Acanthogyrus maroccanus (Dollfus, 1951) from ***Luciobarbus setivimensis*** (Morocco)

Acanthogyrus nigeriensis (Dollfus et Golvan, 1956) from ***Labeo coubie*** (Mali)

Acanthogyrus phillipi (Mashego, 1988) from ***Enteromius neefi*** (South Africa)

Acanthogyrus tilapiae (Baylis, 1948) from *Aristochromis christyi*, *Bagrus meridionalis*, *Coptodon guineensis*, *C. rendalli*, *C. zillii*, *Ctenopharynx pictus*, *Genyochromis mento*, *Haplochromis squamipinnis*, *Haplochromis* sp., *Hemichromis bimaculatus*, *H. fasciatus*, *Labeotropheus fuelleborni*, *Lichnochromis acuticeps*, *Maylandia emmiltos*, *M. zebra*, *Mchenga thinos*, *Melanochromis auratus*, *M. heterochromis*, *M. vermivorus*, *Nimbochromis polystigma*, *Oreochromis andersonii*, *O. esculentus*, *O. leucostictus*, ***O. lidole*** (Tanzania), *O. macrochir*, *O. niloticus*, *O. tanganicae*, *Oreochromis* sp., *Petrotilapia genalutea*, *Placidochromis johnstoni*, *Protomelas annectens*, *P. taeniolatus*, *Pseudotropheus elongatus*, *Sarotherodon galilaeus*, *S. melanotheron*, *Stigmatochromis woodi*, *Tetraodon lineatus*, *Trematocranus placodon*, *Tropheops microstoma*, *T. tropheops*, *Tyrannochromis macrostoma*

Pararaosentis Amin, Heckmann, Ha, Luc et Doanh, 2000

Pararaosentis golvani (Troncy et Vassiliadès, 1973) from *Schilbe mystus*, ***Synodontis batensoda*** (Senegal), *S. frontosus*, *S. membranaceus*, *Tetraodon lineatus* [Fig. 4.7.3C]

Neoechinorhynchida Ward, 1917

Keys to the genera of the Neoechinorhynchida from African freshwater fishes

1 (2) Trunk without dendritic nuclei; proboscis short and subglobular or subcylindrical, armed with a small number of hooks arranged in spiral, circular, or diagonal rows (family Neoechinorhynchidae)……3

2 (1) Proboscis relatively long and cylindrical, armed with many hooks arranged quincuncially, in longitudinal rows. Parasites of fishes (family Tenuisentidae) [Fig. 4.7.3B]…….***Tenuisentis***

3 (4) Six hooks in each of three circles of hooks on the proboscis [Fig. 4.7.3D] ……...***Neoechinorhynchus***

4 (3) Proboscis armed with 6 hooks per circle; anterior trunk with 7 circles of tiny spines [Fig. 4.7.3E]……..***Hexaspiron***

List of the Neoechinorhynchida from African freshwater fishes

Tenuisentidae Van Cleave, 1936

Tenuisentis Van Cleave, 1936

Tenuisentis niloticus (Meyer, 1932) from ***Heterotis niloticus*** (Egypt), *Hydrocynus brevis*, *Lates niloticus* [Fig. 4.7.3B]

Neoechinorhynchidae Van Cleave, 1919

Hexaspiron Dollfus et Golvan, 1956

Hexaspiron nigericum Dollfus et Golvan, 1956 from ***Synodontis membranaceus*** (Nigeria) [Fig. 4.7.3E]

Neoechinorhynchus Stiles et Hassall, 1905

Neoechinorhynchus africanus Troncy, 1970 from ***Citharinops distichodoides*** (Chad), *Citharinus citharus*, *Hydrocynus forskahlii*, *Synodontis membranaceus* [Fig. 4.7.3D]

Neoechinorhynchus ichthyobori Saoud, El-Naffar et Abu-Sinna, 1974 from *Chelon ramada*, ***Ichthyborus besse*** (Sudan)

Neoechinorhynchus rutili (Müller, 1780) from *Clarias gariepinus*

Neoechinorhynchus sp. from *Citharinus citharus*, *Clarias gariepinus*

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Chapter 4.8.
NEMATODA

Šárka MAŠOVÁ & Roman KUCHTA

Nematodes or roundworms (Nematoda) – basic characteristics, life cycles, classification and principal diagnostic features

- roundworms (Ecdysozoa: Nematoda)
- nearly 25,000 species described
- only some groups parasitic in vertebrates
- endoparasites of different organs and tissues
- mostly long narrow cylindrical body, round in cross section, tapered towards both ends
- pseudocoelom
- body surface covered with cuticle
- well-developed digestive tract
- gonochoristic (separate sexes)
- direct or indirect life cycles (Fig. 4.8.1) (monoxeny or heteroxeny)
- four changes of cuticle (moulting)
- causative agents of human fish-borne diseases (*e.g.*, anisakiasis, gnathostomiasis)

Generally, life cycles differ depending upon the species of nematode (Yanong 2002). Development of almost all species of fish nematodes requires an intermediate host with presumable exceptions in some groups such as Capillariidae (see Moravec 2013). A complete nematode life cycle consists of four larval stages (L), separated from one another by a moult (or ecdysis) followed by an immature adult (or subadult): egg → L1 → L2 → L3 → L4 → adult. Larval stages of monoxenous species (with direct life cycle) undergo two transformations after hatching (*e.g.*, Pharyngodonidae). Infective juveniles (L3) may be ingested and mature in the intestine or infect via penetrating the skin and migrate through tissues.

Heteroxenous nematodes (with indirect life cycle) involve one or more intermediate hosts (*e.g.*, *Camallanus* sp. – see Fig. 4.8.1). The first two moults usually occur in the intermediate host. Infection of the definitive host by the L3 is either via ingestion of the intermediate host or inoculation by the intermediate host (Gaugler & Bilgrami 2004).

The classification of nematodes presented here is based on a combination of Moravec (2013), Hodda (2011) and the traditional consensus of nematode relationships according to Blaxter et al. (1998). This presentation includes only parasitic nematode families reported from Africa. Higher-level classification (classes, orders and families) of nematodes is based mainly on the type and morphology of the oesophagus, the anterior part of the digestive tract, the

structure of the anterior end (type of oral opening, lips, interlabia, teeth, buccal cavity, cuticular structures), presence/absence of phasmids, presence and number of caudal papillae, presence/absence of stichosome or trophosome, presence/absence of lateral canals in the excretory system and structure of its terminal duct, type of eggs, morphology of the reproductive system (type of uterus, presence/absence of caudal bursa in males), presence/absence of the precloacal sucker, position of the vulva, etc. (Fig. 4.8.2; see Anderson et al. 2009; Gibbons 2010 for keys up to the genus level).

Generic classification and species identification are based on the details of the anterior end (*e.g.*, deirids, structure of the buccal capsule), the morphology of the male copulatory organs (*e.g.*, spicules, gubernaculum, copulatory bursa), detailed structure of the digestive system (*e.g.*, ventriculus, intestinal caecum, oesophagus, pharynx). Other morphological characteristics used for identification include body size and the proportional size of individual parts (*e.g.*, oesophagus, caeca, tail, position of the vulva) to body length; the position of the excretory pore and the nerve ring, structure of the cuticle; the structures or projections of the eggs and the number and position of caudal papillae. For identification, the infection site and host taxon are also very often important.

Fig. 4.8.1. Heteroxenous (indirect) life cycle of *Camallanus* sp.; copepods serve as intermediate hosts. (Illustration by M. Luo.)

Glossary of taxonomically important morphological characteristics of nematodes

ala (plural alae): thin (flat) cuticular protrusion or fin, running longitudinally, usually lateral or sublateral, frequently paired; cervical alae (see below) on the anterior end; caudal alae on the posterior end of males

amphid: complex sensilla at the anterior body end with chemoreceptory function; its primitive position is lateral and postlabial; opening to the exterior usually as a simple pore [Fig. 4.8.2A-C]

bacillary bands: modification of hypodermis, consisting of longitudinal rows of columnar cells that have pore-like openings to the surface of cuticle (in Trichuroidea) (Anderson *et al.* 2009)

boss (plural bosses): any protruberant part, prominence or swelling of cuticle (*e.g.*, *Galeiceps*, *Philometroides*, *Nilonema*)

bulb or bulbus: bulbous inflation usually in the posterior part of the oesophagus in certain nematodes (*e.g.*, Pharyngodonidae), forces the food into the intestine [Fig. 4.8.2E]

cervical alae: in some parasitic nematodes, wide lateral anterior alae (single, bifid or trifid, often with internal supporting struts)

cheilostome: anterior region of the mouth (stoma), which is lined by external cuticle formation and is not surrounded by oesophageal tissues

collar: any of various structures comparable with a collar (*e.g.*, *Galeiceps*)

collarette: usually anterior cuticular extensions forming an annular ring in the neck region (*e.g.*, Physalopteroidea or *Pseudoproleptus*)

copulatory bursa: copulatory accessorial organ, formed by greatly expanded caudal alae in male tail end of certain parasitic nematodes

corpus: anterior part of oesophagus, acts as a suction pump

deirids (cervical papillae): peripheral somatic sense organs in the anterior part of the body, very often near nerve ring, considered to act as a mechanoreceptor [Fig. 4.8.2N-P]

didelphic: having two uteri

gubernaculum: sclerotised dorsal and lateral walls of the distal cloaca form the gubernaculum that guides the spicules when protracting or retracting and protects the underlying tissue [Fig. 4.8.2R-T]

interlabium: small lobe situated between the lips in certain nematodes [Fig. 4.8.2C]

intestinal caecum: appendage of the intestine extending anteriorly to the oesophagus [Fig. 4.8.2G-J]

isthmus: constriction of the oesophagus, region between corpus and bulb [Fig. 4.8.2E]