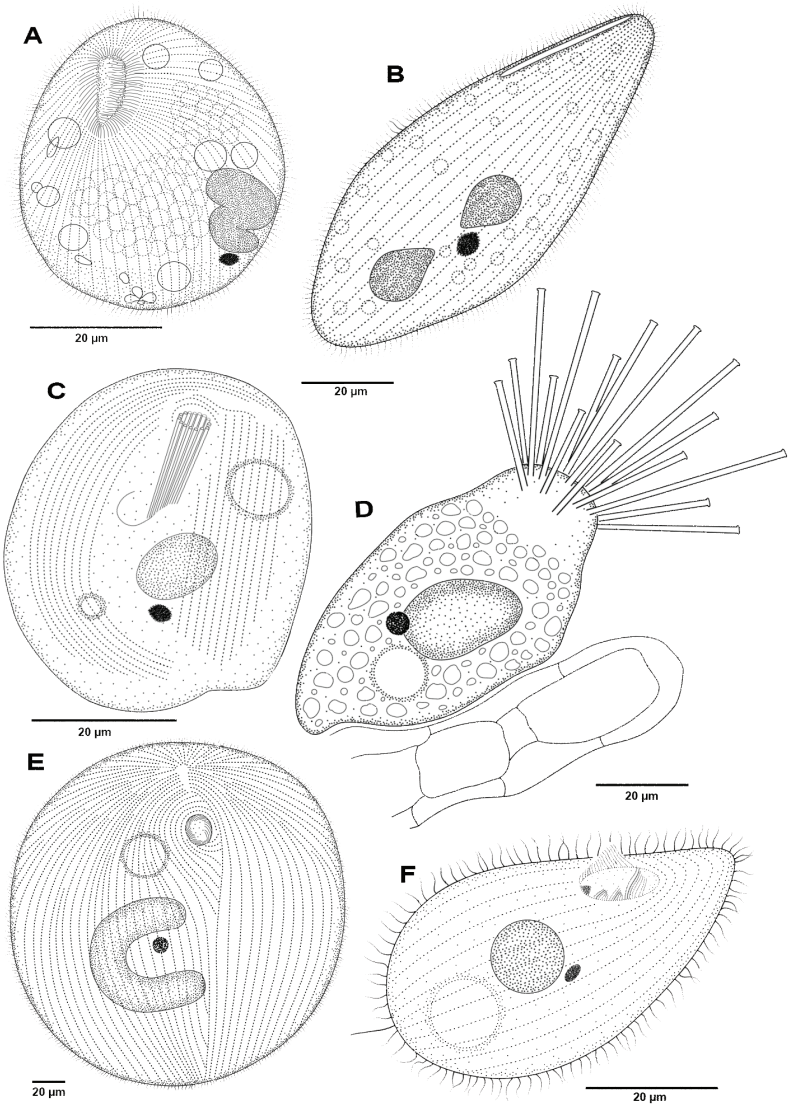

Fig. 4.2.4. Schematic line drawings of ciliophorans. **A.** *Balantidium polyvacuolum* Li, 1963 from *Xenocypris argentea*; **B.** *Amphileptus branchiarum* Wenrich, 1924 from a freshwater fish; **C.** *Chilodonella piscicola* (Zacharias, 1894) from *Tilapia sparrmanii*; **D.** *Capriniana piscium* (Buetschli, 1889) from *Perca fluviatilis*; **E.** *Ichthyophthirius multifiliis* Fouquet, 1876 from *Oreochromis mossambicus*; **F.** *Tetrahymena corlissi* Thompson, 1955 from a freshwater fish. (Modified from Li 1963; Lom & Dyková 1992.)

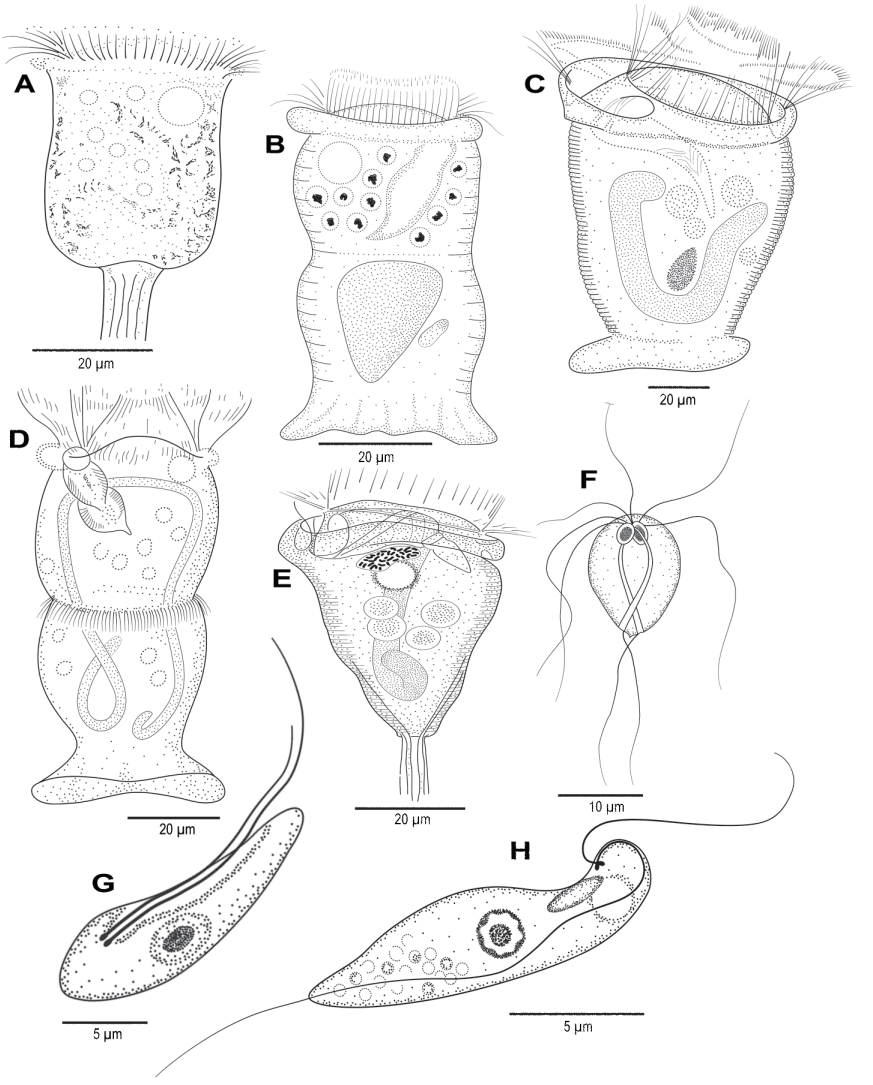

Fig. 4.2.5. Schematic line drawings. **A.** *Epistylis transvaalensis* Viljoen et Van As, 1983 from *Pseudocrenilabrus philander*; **B.** *Apiosoma dermatum* Viljoen et Van As, 1983 from *Oreochromis mossambicus*; **C.** *Riboscyphidia arctica* (Zhukov, 1962) from *Liparis* sp.; **D.** *Ambiphrya neobolae* Viljoen et Van As, 1985 from *Neobola brevianalis*; **E.** *Vorticella* sp. from a freshwater fish; **F.** *Hexamita salmonis* (Moore, 1923) from *Salmo trutta*; **G.** *Ichthyobodo necator* (Henneguy, 1883) from *Cyprinus carpio*; **H.** *Cryptobia branchialis* Nie in Chen, 1955 from *Clarias gariepinus*. (Modified from Viljoen & Van As 1983, 1985; Lom & Dyková 1992; Lom & de Puytorac 1994.)

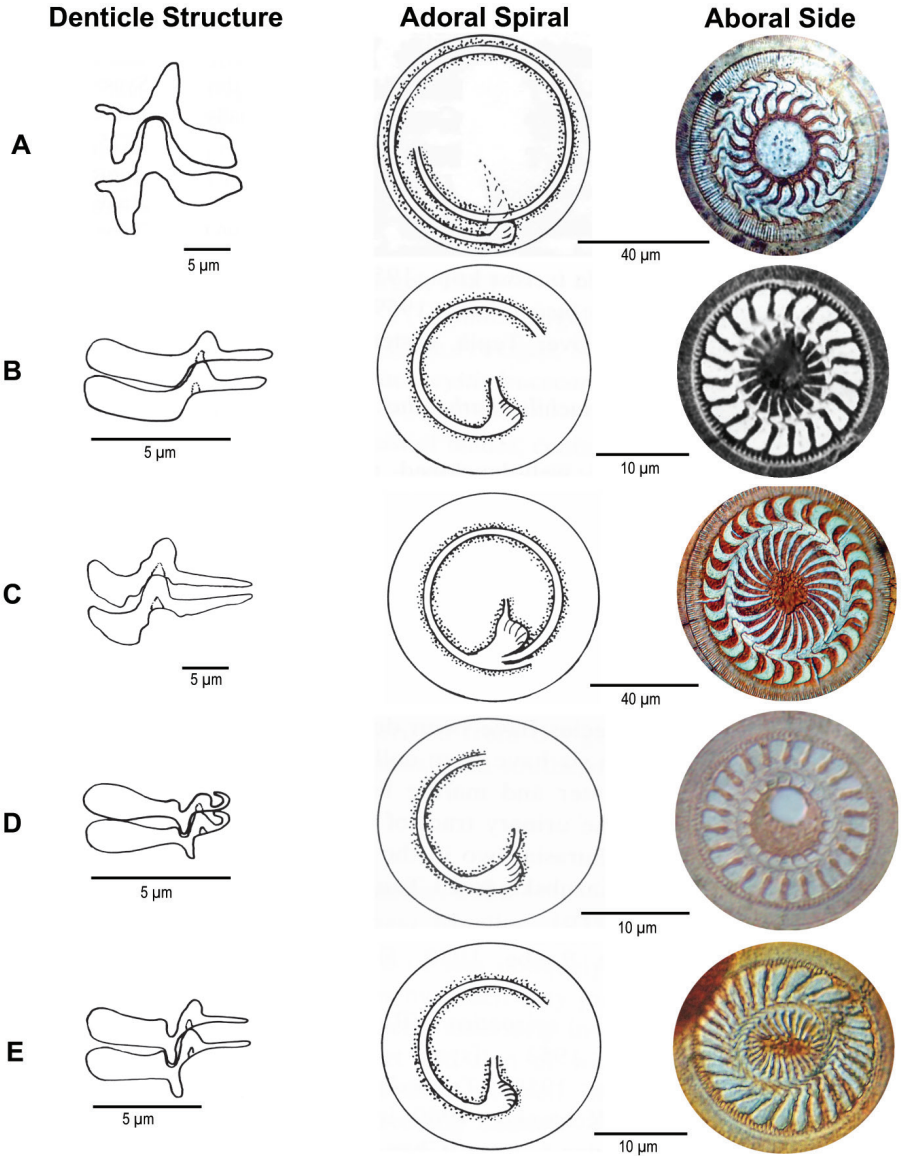

Fig. 4.2.6. Schematic line drawings and silver impregnated adhesives discs of five genera of trichodinids. **A.** *Hemitrichodina robusta* Basson et Van As, 1989 from *Marcusenius macrolepidotus*; **B.** *Paratrichodina corlissi* Lom et Haldar, 1977 from *Gobio* sp.; **C.** *Trichodina magna* Van As et Basson, 1989 from *Oreochromis mossambicus*; **D.** *Trichodinella epizootica* (Raabe, 1950) from *Enteromius paludinosus*; **E.** *Tripartiella ctenopomae* Basson et Van As, 2002 from *Ctenopoma multispine*. (Modified from Basson & Van As, 1989; micrographs by L. Basson except for B, which was provided by the late J. Lom.)

AMOEBOZOA Lühe, 1913

Archaomoebae Cavalier-Smith, 1983 – **Entamoebidae** Chatton, 1925

Amoeboid organisms – basic characteristics

- amoebae infecting fish either specific endocommensals or free-living (see Dyková 2008)
- only species of *Entamoeba* reported from African fishes
- cilia and centrioles absent
- contain mitosomes instead of classical mitochondria
- peroxisome-absent
- mitosis closed with endonuclear centrosomes and spindle
- reduced Golgi dictyosome

List of amoeboid protists in African freshwater fishes

Note: Dyková *et al.* (2005) characterised 17 strains of flattened amoebae from fishes obtained from various sources and deposited at the Institute of Parasitology, Biology Centre of the Czech Academy of Sciences. Mention is made of two freshwater strains imported from Africa, both from the gills of *Clarias angolensis* that formed part of the analyses in their study.

Entamoeba Cassagrandi et Barbagallo, 1895

Entamoeba synodontis Imam, Ramadan and Derahlli, 1987 from ***Synodontis schall*** (Egypt)*

Entamoeba sp. on the skin and gills of *Clarias gariepinus* [Fig. 4.2.2A]

OPISTHOKONTA Cavalier-Smith, 1987

Ichthyosporea Cavalier-Smith, 1998 – **Rhinosporidaceae** Mendoza *et al.*, 2001

Ichthyosporeans – basic characteristics

- posterior cilia, if cilia present
- flat mitochondrial cristae present (folds of mitochondrial inner membrane)
- parasitic forms spherical phenotypes with several endospores 2-20 µm in diameter eventually released, becoming mature cells with endospores to continue with the parasitic cycle

List of ichthyosporeans from African freshwater fishes

Dermocystidium Pérez, 1908

Dermocystidium sp. on the skin of *Carassius auratus* and *Cyprinus carpio* [Fig. 4.2.2B]

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*The type species of parasite genera and type host of species are highlighted in bold. The country where the type locality lies is also provided if known.

Fungi Moore, 1980 – **Microsporidia** Balbiani, 1882

Microsporidia – basic characteristics

- parasites of nearly all animal phyla, with the majority of species associated with arthropods and fishes
- obligate intracellular parasites, usually of animals
- mitochondria reduced to mitosomes
- spores with inner chitin walls and outer proteinaceous walls
- without kinetosomes, centrioles or cilia
- centrosomal plaque
- extrusive specialised polar tube for host penetration
- reproduction sexual, asexual or both
- systematic subdivisions uncertain at this time
- many of those genera that are found as parasites in fishes exhibit a complex coexistence with their host cell that includes a special type of hypertrophy, forming structures known as xenomas
- about 100 microsporidian species known from fishes (see Lom 2002)

List of microsporidians from African freshwater fishes

Loma Morrison et Sprague, 1981

Loma camerounensis Fomena, Coste et Bouix, 1992 in subepithelial connective tissue of the intestine of ***Oreochromis niloticus*** (Cameroon) [Fig. 4.2.2C]

Neonosemoides Faye, Toguebaye et Bouix, 1996

Neonosemoides tilapiae Faye, Toguebaye et Bouix, 1996 in the stomach of ***Coptodon guineensis*** (Senegal)

Neonosemoides sp. in the gills of *Chrysichthys auratus* [Fig. 4.2.2D]

Pleistophora Gurley, 1893

Pleistophora-like species in the swim-bladder of *Haplochromis angustifrons* and *H. elegans* [Fig. 4.2.2E]

Unikaryon Canning, Lai et Lie, 1974

Unikaryon nomimoscolexi Sene, Ba, Marcand et Toguebaye, 1997 in the cestode *Nomimoscolex* sp. from ***Clarotes laticeps*** (Senegal), *i.e.*, hyperparasite [Fig. 4.2.1F] [the cestode was certainly misidentified as species of *Nomimoscolex* occur in the Neotropical region; it was most likely *Proteocephalus sulcatus* – see Chapter 4.6]

Unidentified microsporidia

Microsporidia gen. sp. from *Clarias gariepinus* (cystozoic), *Oreochromis niloticus* (skin and gills), *Parachanna obscura*, *Synodontis schall*, *S. ocellifer* (both in stomach and intestine)

SAR (Alveolata, Rhizaria and Stramenopiles)

Stramenopiles Patterson, 1989 – **Opalinata** Wenyon, 1926

Opalins – basic characteristics

- slowly swimming large protists
- covered with numerous cilia arranged in longitudinal, or slightly helicoidal, densely spaced rows
- multiciliated cells with cilia originating from anterior morphogenetic centre, the falx, forming oblique longitudinal rows or files
- microtubular ribbons supporting longitudinal pellicular ridges between ciliary rows
- two to many monomorphic nuclei
- life cycle complex, with sexual processes induced by hormones of host and linked to host's life cycle
- endobionts in amphibians and some fishes (Adl *et al.* 2012).

List of opalins from African freshwater fishes

Protoopalina Metcalf, 1918

Protoopalina sp. in the intestine of *Clarias gariepinus* [Fig. 4.2.2G]

Alveolata Cavalier-Smith, 1991 – **Dinoflagellata** Bütschli, 1885

Dinoflagellates – basic characteristics

- dinoflagellates in fishes with the parasitic stage in the life cycle predominating over the dinospore stage
- cells with two cilia in motile stage
- nucleus typically a dinokaryon (nucleus where chromosomes are fibrillar in appearance and condensed)
- closed dinomitosis (mitosis specifically involving dinokaryon) with extra nuclear spindle

List of dinoflagellates from African freshwater fishes

Piscinoodinium Lom, 1981

Piscinoodinium sp. in the skin and gills of *Clarias gariepinus* [Fig. 4.2.2H]

Apicomplexa Levine, 1980 **– Coccidia** Leuckart, 1879 **(Eimeriorina** Léger, 1911**)**

Coccidia – basic characteristics

- elaborate and intricate apical complex always present
- oocysts always formed

- sporozoites with a three-layered pellicle
- micro- and macrogametes develop independently
- microgamonts produce large numbers of ciliated microgametes
- zygote nonmotile
- sporozoites always enclosed in sporocyst within oocysts

List of coccidia from African freshwater fishes

Eimeria Schneider, 1875

Eimeria sp. from *Clarias* spp. (intestine) and *Synodontis schall* [Fig. 4.2.2I]

Goussia Labbé, 1896

Goussia anopli Molnár, Avenant-Oldewage et Székely, 2004 in mucus and epithelium of the foregut of ***Enteromius anoplus*** (South Africa) [Fig. 4.2.2J]

Goussia cichlidarum Landsberg et Paperna, 1985 in the swim bladder of *Coptodon zillii*, *Oreochromis aureus*, *O. niloticus*, ***Oreochromis* sp.** (Uganda)

Goussia molnarica El-Mansy, 2008 in the intestine of ***Clarias gariepinus*** (Egypt)

Goussia vanasi (Landsberg et Paperna, 1987) [syn. *Eimeria vanasi* Landsberg and Paperna, 1987] in the intestine of *Oreochromis mossambicus*, *Pseudocrenilabrus philander*, *Tilapia sparrmanii* (South Africa)

Coccidia sp. in the intestine of *Chrysichthys nigrodigitatus*

Apicomplexa Levine, 1980 **– Coccidia** Leuckart, 1879 **(Adeleorina** Léger, 1911**)**

Haemogregarines – basic characteristics

- obligate endoparasitic intracellular protists in the blood of a range of vertebrates
- transmitted by invertebrate haematophagous vectors (flies, bugs, ticks and leeches)
- around 400 species recorded globally in vertebrates and invertebrate vectors
- apical complex in infective stages (merozoites, sporozoites)
- heteroxenous, asexual development (including merogony and gamogony) in vertebrate host
- sexual development (including gametogenesis, syngamy, ookinete formation and sporogony) in invertebrate vector
- transfer of infective stages to and from the invertebrate vector presumed to be inoculative
- leeches implicated as the invertebrate vector for most African genera

List of haemogregarines from African freshwater fishes

Babesiosoma Jakowski et Nigrelli, 1956

Babesiosoma hannesi (Paperna, 1981) from *Chelon dumerili*, *Chelon richardsonii*, ***Mugil cephalus*** (South Africa) [Fish inhabiting marine, freshwater and brackish systems.]

Babesiosoma mariae (Hoare, 1930) [syn. *Dactylosoma mariae* Hoare, 1930] from *Astatoreochromis alluaudi*, *Haplochromis cinereus*, *H. nubilus*, *H. serranus*, ***Haplochromis* spp**. (Uganda), *Labeo victorianus*, *Oreochromis esculentus*, *O. niloticus*, *O. variabilis*, *Serranochromis angusticeps* [Fig. 4.2.3A]

Cyrilia Lainson, 1981

Cyrilia nili (Wenyon, 1909) [syn. *Haemogregarina nili*] from ***Parachanna obscura*** (Sudan) [Fig. 4.2.3B]

Desseria Siddall, 1995

Desseria sp. from *Mugil cephalus* [This species was described in detail by Smit *et al.* (2002), but not named. As such it has been provisionally included here.] [Fig. 4.2.3C]

Haemogregarine gen. sp. from *Synodontis schall*

Ciliophora Doflein, 1901

Ciliophorans – basic characteristics

- among the most common and widely distributed symbionts of fishes, whether as parasites or as ecto- and endocommensals
- monograph by Lynn (2008) gives an overview of these organisms
- highly organised protists with a pellicle covering cell body
- pellicle covered by cilia, may be grouped to form compound ciliary organelles
- ciliature may be reduced in some groups, or completely absent
- infraciliature (complex fibrillar network) associated with cilia's basal bodies
- one to several diploid macronuclei and one to several polyploid macronuclei
- transverse (homothetogenic) binary fission, rarely budding or multiple fission
- conjugation occurs as sexual reproduction process
- complex buccal apparatus used for feeding, but some groups secondarily astome
- found on the surface or inside animal hosts (variety of symbiotic associations with hosts)

List of ciliophorans from African freshwater fishes

In the following survey, ciliophorans are listed according to their 5th and 6th taxonomic rank (see Table 4.2.1), *i.e.*, Trichostomatia (genera *Amphileptus* and *Balantidium*), Phyllopharyngea (*Chilodonella*), Suctoria (*Capriniana*), Oligohymenophorea – Hymenostomatia (*Ichthyophthirius* and *Tetrahymena*), Oligohymenophorea – Peritrichia (Sessilida: *Ambiphrya*, *Apiosoma*, *Epistylis*, *Riboscyphidia*, *Vorticella*), and Oligohymenophorea – Peritrichia (Mobilida: *Hemitrichodina*, *Paratrichodina*, *Trichodina*, *Trichodinella*, *Tripartiella*).

Trichostomatia Bütschli, 1889

Amphileptus Ehrenberg, 1830

Amphileptus niloticus El-Tantawy, Abdel-Aziz, Abou El-Nour, Samn, Shaldoum et Rady, 2016 on the skin and gills of ***Lates niloticus*** (Egypt)

Amphileptus sp. on the gills of *Clarias gariepinus*, *Lates niloticus*, *Sarotherodon galilaeus* [Fig. 4.2.4B]

Balantidium Claparède et Lachmann, 1858

Balantidium sp. from *Clarias gariepinus* and *Synodontis schall* [Fig. 4.2.4A]

Phyllopharyngea de Puytorac *et al.*, 1974

Chilodonella Strand, 1926

Chilodonella hexasticha (Kiernik, 1909) on the skin, fins and gills of *Carassius auratus*, *Clarias gariepinus*, *Coptodon rendalli*, *C. zillii*, *Enteromius paludinosus*, *Oreochromis mossambicus*, *O. niloticus*, *Pseudocrenilabrus philander*, *Sarotherodon galilaeus*, *Tilapia sparrmanii*

Chilodonella piscicola (Zacharias, 1894) [syn. *C. cyprini* (Moroff, 1902)] from *Coptodon rendalli*, *Oreochromis mossambicus*, *Pseudocrenilabrus philander*, *Tilapia sparrmanii* [Fig. 4.2.4C]

Chilodonella sp. on the skin and gills of *Clarias gariepinus*, *Clarias* sp., *Cyprinus carpio*, *Heterobranchus bidorsalis*, *H. longifilis*, *Oreochromis mossambicus*, *O. niloticus*, *Synodontis schall*

Suctoria Claparède et Lachmann, 1858

Capriniana Mazzarelli, 1906 [syn. *Trichophrya* Claparède et Lachmann, 1858]

Capriniana sp. on the skin and gills of *Clarias gariepinus* [Fig. 4.2.4D]

Oligohymenophorea de Puytorac *et al.*, 1974 – **Hymenostomatia** Delage et Hérouard, 1896

Ichthyophthirius Fouquet, 1876

Ichthyophthirius multifiliis Fouquet, 1876 on the skin, fins and gills of *Anguilla mossambica*, *Carassius auratus*, *Chrysichthys auratus*, *Clarias gariepinus*, *Cyprinus carpio*, *Enteromius paludinosus*, *Heterobranchus longifilis*, *Labeobarbus aeneus*,

Oncorhynchus mykiss, *Oreochromis mossambicus*, *O. niloticus*, *Poecilia reticulata*, *Salmo trutta* [Fig. 4.2.4E]

Ichthyophthirius sp. on the skin and gills of *Carassius auratus*, *Clarias gariepinus*, *Oreochromis niloticus*, *Synodontis schall*

Tetrahymena Furgason, 1940

Tetrahymena corlissi Thompson, 1955 on the skin of *Sarotherodon galilaeus* [Fig. 4.2.4F]

Tetrahymena pyriformis (Ehrenberg, 1830) on the skin and gills of *Coptodon zillii*, *Cyprinus carpio*, *Enteromius paludinosus*, *Oreochromis leucostictus*

Tetrahymena sp. on the skin and gills of *Clarias gariepinus*, *Lates niloticus*

Oligohymenophorea de Puytorac *et al.*, 1974 – **Peritrichia** Stein, 1859 (Sessilida Kahl, 1935)

Ambiphrya Raabe, 1952

Ambiphrya ameiuri Davis, 1947 on the skin and gills of *Lates niloticus*, *Sarotherodon galilaeus*

Ambiphrya neobolae Viljoen et Van As, 1985 on the skin of ***Mesobola brevianalis*** (South Africa) [Fig. 4.2.5D]

Ambiphrya sp. on the skin and gills of *Clarias gariepinus*, *Lates niloticus*

Apiosoma Blanchard, 1885 [syns *Glossatella* Bütschli, 1889; *Scopulata* Viljoen and Van As, 1985]

Apiosoma amoebae (Grenfell, 1887) [syn. *Glossatella amoebae* Grenfell, 1887] on the gills of *Lates niloticus*

Apiosoma caulata Viljoen et Van As, 1985 on the skin and gills of ***Mesobola brevianalis*** (South Africa)

Apiosoma conica Shulman, 1984 on the gills of *Coptodon zillii*

Apiosoma constricta (Viljoen et Van As, 1985) [syn. *Scopulata constricta* Viljoen et Van As, 1985] on the skin of *Coptodon rendalli*, *Enteromius trimaculatus*, *Marcusenius macrolepidotus*, *Micralestes acutidens*, ***Oreochromis mossambicus*** (South Africa)**,** *Pseudocrenilabrus philander*, *Tilapia sparrmanii*

Apiosoma curvinucleata Viljoen et Van As, 1985 on the skin of ***Oreochromis mossambicus*** (South Africa)

Apiosoma dermatum (Viljoen et Van As, 1983) [syn. *Scopulata dermata* Viljoen et Van As, 1983] on the skin of *Coptodon rendalli, Enteromius trimaculatus*, *Marcusenius macrolepidotus*, *Micralestes acutidens*, ***Oreochromis mossambicus*** (South Africa), *Pseudocrenilabrus philander*, *Tilapia sparrmanii* [Fig. 4.2.5B]

Apiosoma doliaris Timofeev, 1962 on the gills of *Lates niloticus*

Apiosoma epibranchialis (Viljoen et Van As, 1983) [syn. *Scopulata epibranchialis* Viljoen et Van As, 1983] on the skin of *Lates niloticus*, *Micropterus dolomieu*, *Oreochromis mossambicus*, ***Pseudocrenilabrus philander*** (South Africa), *Sarotherodon galilaeus*

Apiosoma micralesti Viljoen et Van As, 1985 on the skin of ***Micralestes acutidens*** (South Africa)

Apiosoma mothlapitsis Viljoen et Van As, 1985 on the skin of ***Labeobarbus marequensis*** (South Africa)

Apiosoma nasalis (Timofeev, 1962) [syn. *Glossatella nasalis* Timofeev, 1962] on the skin and gills of *Pseudocrenilabrus philander*

Apiosoma obliqua Viljoen et Van As, 1985 on the skin of ***Labeo cylindricus*** (South Africa)

Apiosoma phiala Viljoen et Van As, 1985 on the skin of ***Enteromius trimaculatus*** (South Africa), *E. marequensis*, *E. paludinosus*, *E. unitaeniatus*, *Labeo capensis*, *L. cylindricus*, *Mesobola brevianalis*, *Oreochromis mossambicus*, *Pseudocrenilabrus philander*

Apiosoma piscicola Blanchard, 1885 on the skin and gills of *Coptodon rendalli*, *C. zillii*, *Enteromius paludinosus*, *E. trimaculatus*, *Labeo cylindricus*, *Lates niloticus*, *Marcusenius macrolepidotus*, *Micropterus dolomieu*, *Oreochromis mossambicus*, *Pseudocrenilabrus philander*

Apiosoma poteriformis (Timofeev, 1962) [syn. *Glossatella poteriformis* Timofeev, 1962] on the gills of *Lates niloticus*

Apiosoma viridis Viljoen et Van As, 1985 on the skin of *Chetia flaviventris*, *Coptodon rendalli*, *Oreochromis mossambicus*, ***Pseudocrenilabrus philander*** (South Africa), *Tilapia sparrmanii*

Apiosoma sp. on the skin and gills of *Oncorhynchus mykiss*, *Synodontis schall*

Epistylis Ehrenberg, 1830

Epistylis transvaalensis Viljoen et Van As, 1983 on the skin of ***Pseudocrenilabrus philander*** (South Africa)

Epistylis sp. on the skin and gills of *Clarias gariepinus*, *Enteromius paludinosus*, *Oreochromis leucostictus*, *O. niloticus* [Fig. 4.2.5A]

Riboscyphidia Jankovski, 1985 (syn. *Scyphidia* Dujardin, 1841, *partim*)

Riboscyphidia doliaris (Chernova, 1977) [syn. *Scyphidia doliaris* Chernova, 1977] on the skin and gills of *Lates niloticus*

Riboscyphidia globularis (Solomatova, 1977) [syn. *Scyphidia globularis* Solomatova, 1977] on the skin and gills of *Lates niloticus*

Riboscyphidia mansourensis (El-Tantawy, Abdel-Aziz, Abou El-Nour, Samn, Shaldoum et Rady, 2016) [syn. *Scyphidia mansourensis* El-Tantawy, Abdel-Aziz, Abou El-Nour, Samn, Shaldoum et Rady, 2016] on the skin and gills of ***Lates niloticus*** (Egypt)

Riboscyphidia sp. on the gills and skin of *Chrysichthys auratus*, *Lates niloticus* [Fig. 4.2.5C]

Vorticella Linnaeus, 1767

Vorticella sp. on the gills and skin of *Clarias gariepinus*, *Sarotherodon galilaeus* [Fig. 4.2.5E]

Oligohymenophorea de Puytorac *et al.*, 1974 – **Peritrichia** Stein, 1859 (order Mobilida Kahl, 1933)

List of trichodinids (Mobilida) in African freshwater fishes

Hemitrichodina Basson et Van As, 1989

Hemitrichodina robusta Basson et Van As, 1989 on the skin and fins, occasionally gills of *Hepsetus cuvieri*, ***Marcusenius macrolepidotus*** (South Africa), *Micralestes acutidens* [Fig. 4.2.6A]

Paratrichodina Lom, 1963

Paratrichodina africana Kazubski et El-Tantawy, 1986 on the gills, rarely body surface of *Lates niloticus*, ***Oreochromis niloticus*** (Egypt), *Sarotherodon galilaeus*, *Tilapia* sp. [Fig. 4.2.6B]

Trichodina Ehrenberg, 1838

Trichodina acuta Lom, 1961 on the skin of *Oncorhynchus mykiss*

Trichodina anabantidarum Basson et Van As, 2002 on the gills, sometimes skin and fins of *Ctenopoma multispine*, ***Microctenopoma intermedium*** (Botswana)

Trichodina centrostrigeata Basson, Van As et Paperna, 1983 on the gills, sometimes skin and fins of *Brycinus lateralis*, *Coptodon rendalli*, *Cyprinus carpio*, *Enteromius* sp., *Hemichromis elongatus*, *Labeo cylindricus*, *Lates niloticus*, *Oreochromis andersonii*, *O. mossambicus*, *O. niloticus*, ***Pseudocrenilabrus philander*** (South Africa), *Serranochromis angusticeps*, *Synodontis leopardinus*, *Tilapia sparrmanii*

Trichodina compacta Van As et Basson, 1989 on the skin and fins of *Chetia flaviventris*, *Chiloglanis pretoriae*, ***Coptodon rendalli*** (South Africa)**,** *Cyprinus carpio*, *Enteromius eutaenia*, *E. radiatus*, *E. trimaculatus*, *Labeo cylindricus*, *Labeobarbus kimberleyensis*, *L. marequensis*, *Lates niloticus*, *Marcusenius macrolepidotus*, *Mesobola brevianalis*, *Micropanchax johnstoni*, *Nannocharax multifasciatus*, *Oreochromis andersonii*, *O. mossambicus*, *Petrocephalus catostoma*, *Pharyngochromis darlingi*, *Pseudocrenilabrus philander*, *Sarotherodon galilaeus*, *Serranochromis angusticeps*, *Tilapia sparrmanii*

Trichodina equatorialis Kazubski, 1986 on the gills of ***Tilapia* sp**. (Kenya)

Trichodina fahaka Al-Rasheid, Ali, Sakran, Abdel-Baki et Abdel Ghaffar, 2000 on the gills of ***Tetraodon lineatus*** [syn. *Tetraodon fahaka*] (Egypt)

Trichodina frenata Van As et Basson, 1992 on the gills of *Lates niloticus*, ***Mastacembelus frenatus*** (Namibia), *Sarotherodon galilaeus*

Trichodina heterodentata Duncan, 1977 on the skin, fins and gills of *Chetia flaviventris*, *Coptodon rendalli*, *Cyprinus carpio*, *Enteromius eutaenia*, *E. paludinosus*, *E. trimaculatus*, *Glossogobius giuris*, *Hydrocynus forskahlii*, *Labeo cylindricus*, *Labeobarbus marequensis*, *Marcusenius macrolepidotus*, *Mesobola brevianalis*, *Micralestes acutidens*, *Micropanchax johnstoni*, *Micropterus salmoides*, *Oreochromis*

mossambicus, *O. niloticus, Petrocephalus catostoma*, *Pseudocrenilabrus philander*, *Synodontis zambezensis*, *Tilapia sparrmanii*

Trichodina kalimbeza Van As et Basson, 1992 on the skin and fins of ***Enteromius fasciolatus*** (Namibia)

Trichodina kazubski Van As et Basson, 1989 on the skin, fins and gills of ***Enteromius paludinosus*** (South Africa), *E. trimaculatus*

Trichodina kwando Van As et Basson, 1992 on the gills, rarely skin and fins of ***Brycinus lateralis*** (Namibia), *Micralestes acutidens*

Trichodina labyrinthipicis Basson et Van As, 2002 on the gills, rarely skin of *Ctenopoma multispine*, ***Microctenopoma intermedium*** (Botswana)

Trichodina lepsii Lom, 1962 from *Lates niloticus*

Trichodina linyanta Van As et Basson, 1992 on the skin and gills of *Hemichromis elongatus*, ***Oreochromis andersonii*** (Namibia)

Trichodina magna Van As et Basson, 1989 on the skin and fins, occasionally gills of *Clarias gariepinus*, ***Coptodon rendalli*** (South Africa), *C. zillii*, *Hepsetus cuvieri*, *Lates niloticus*, *Marcusenius macrolepidotus*, *Mesobola brevianalis*, *Micropanchax johnstoni*, *Micropterus salmoides*, *Oreochromis andersonii*, *O. mossambicus*, *O. niloticus*, *Petrocephalus catostoma*, *Pseudocrenilabrus philander*, *Sarotherodon galilaeus*, *Schilbe mystus*, *Serranochromis angusticeps*, *Tilapia sparrmanii* [Fig. 4.2.6C]

Trichodina maritinkae Basson et Van As, 1991 on the gills of *Clarias stappersii*, ***C. gariepinus*** (South Africa), *Heterobranchus longifilis*

Trichodina matsu Basson et Van As, 1994 on the gills of *Clarias gariepinus*

Trichodina microspina Van As et Basson, 1992 on the skin and fins, occasionally gills of ***Ctenopoma multispine*** (Namibia), *Microctenopoma intermedium*

Trichodina minuta Basson, Van As et Paperna, 1983 from the skin, fins and gills of *Enteromius trimaculatus*, *Hemichromis elongatus*, ***Oreochromis mossambicus*** (South Africa), *Pseudocrenilabrus philander*, *Tilapia sparrmanii*

Trichodina mutabilis Kazubski et Migala, 1968 on the skin and gills of *Carassius auratus*, *Oreochromis niloticus*

Trichodina ngoma Van As et Basson, 1992 on the skin, fins and gills of ***Nannocharax multifasciatus*** (Namibia)

Trichodina nigra Lom, 1961 on the skin, fins and gills of *Enteromius paludinosus*, *Oreochromis mossambicus*, *Pseudocrenilabrus philander*, *Tilapia sparrmanii*

Trichodina nkasa Van As et Basson, 1992 on the gills of *Synodontis leopardinus*, ***S. macrostigma*** (Namibia)

Trichodina nobilis Chen, 1963 on the skin and gills of *Cyprinus carpio*

Trichodina rectuncinata Raabe, 1958 from *Clarias gariepinus*, *Lates niloticus*, *Oreochromis niloticus*

Note: this species was probably misidentified because it is a marine trichodinid, described from various parts of the world from the gills of various marine fish hosts. The identification of this record cannot be verified as none of the authors provided any morphological data or micrographs.

Trichodina reticulata Hirschmann et Partsch, 1955 on the skin and gills of *Carassius auratus*, *Cyprinus carpio*, *Oreochromis niloticus*

Trichodina sangwala Van As et Basson, 1992 on the gills of *Clarias gariepinus*, ***Schilbe mystus*** (South Africa)

Trichodina uniforma Van As et Basson, 1989 on the skin, fins and gills of ***Carassius auratus*** (South Africa)

Trichodina uretra Basson, 1989 in the urinary bladder and ureters of ***Enteromius trimaculatus*** (South Africa)

Trichodina sp. on the skin and gills of *Clarias gariepinus*, *Coptodon zillii*, *Cyprinus carpio*, *Enteromius paludinosus*, *Heterobranchus bidorsalis*, *H. longifilis*, *Oncorhynchus mykiss*, *Oreochromis leucostictus*, *O. niloticus*, *Protopterus annectens*, *Salmo trutta*, *Synodontis schall*

Trichodinella Raabe, 1950

Trichodinella crennulata Basson et Van As, 1987 on the gills of ***Micralestes acutidens*** (South Africa)

Trichodinella epizootica (Raabe, 1950) on the gills of *Anguilla anguilla*, *Coptodon rendalli*, *C. zillii*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Enteromius paludinosus*, *E. trimaculatus*, *Mesobola brevianalis*, *Mormyrus kannume*, *Oreochromis mossambicus*, *Pseudocrenilabrus philander* [Fig. 4.2.6D]

Trichodinella sp. on the skin and gills of *Coptodon zillii*, *Cyprinus carpio*, *Enteromius paludinosus*, *Oreochromis leucostictus*

Tripartiella Lom, 1959

Tripartiella clavodonta Basson et Van As, 1987 on the gills of *Mesobola brevianalis*, ***Oreochromis mossambicus*** (South Africa), *Pseudocrenilabrus philander*

Tripartiella ctenopomae Basson et Van As, 2002 on the gills of ***Ctenopoma multispine*** (Botswana) [Fig. 4.2.6E]

Tripartiella dactylodentata Al-Rasheid, Ali, Sakran, Abdel-Baki et Ghaffar, 2000 on the gills of ***Mormyrus kannume*** (Egypt)

Tripartiella lechridens Basson et Van As, 1987 on the gills of *Cyprinus carpio*, *Enteromius paludinosus*, *E. trimaculatus*, ***Labeo cylindricus*** (South Africa), *Mesobola brevianalis*, *Micralestes acutidens*, *Oreochromis mossambicus*

Tripartiella leptospina Basson et Van As, 1987 on the gills of ***Oreochromis mossambicus*** (South Africa)

Tripartiella macrosoma Basson et Van As, 1987 on the gills of ***Enteromius eutaenia*** (South Africa)

Tripartiella microctenopomae Basson et Van As, 2002 on the gills of ***Microctenopoma intermedium*** (Botswana)

Tripartiella nana Basson et Van As, 1987 on the gills of ***Oreochromis mossambicus*** (South Africa)

Tripartiella orthodens Basson et Van As, 1987 on the gills of ***Coptodon rendalli*** (South Africa), *Sarotherodon galilaeus*

EXCAVATA Cavalier-Smith, 2002

Diplomonadida Wenyon, 1926 – **Hexamitinae** Kent, 1880

Diplomonadids – basic characteristics

- with a pair of kinetids and two nuclei, each kinetid usually with four kinetosomes and flagella (sometimes three or two), or uncommonly, one kinetid and nucleus
- with a pair of kinetids and two nuclei, each kinetid usually with four kinetosomes and flagella (sometimes three or two), or uncommonly, one kinetid and nucleus
- at least one flagellum per kinetid directed posteriorly, associated with a cytopharyngeal tube or groove, or lying axially within the cell
- various non-microtubular fibres supporting nucleus and cytopharyngeal apparatus
- free-living or endobiotic, often parasitic
- with functional feeding apparatuses
- with an alternate genetic code (TAR codon for glutamine)

List of diplomonadids from African freshwater fishes

Hexamita Dujardin, 1838

Hexamita africanus Imam, Ramadan et Derahli, 1987 from ***Synodontis schall*** (Egypt)

Hexamita sp. in the stomach and intestine of *Clarias gariepinus*, *Coptodon rendalli*, *Heterobranchus longifilis*, *Oreochromis niloticus*, *Sarotherodon galilaeus*, *Synodontis schall* [Fig. 4.2.5F]

Euglenozoa Cavalier-Smith, 1981 – **Prokinetoplastina** Vickerman in Moreira *et al.*, 2004

Prokinetoplastins – basic characteristics

- cells with two (occasionally one, rarely more) flagella, inserted into an apical/subapical flagellar pocket

- with rare exception, emergent flagella with paraxonemal rods
- usually with tubular feeding apparatus associated with flagellar apparatus
- basic flagellar apparatus pattern consisting of two functional kinetosomes and three asymmetrical arranged microtubular roots
- mostly with discoidal cristae

List of prokinetoplastins from African freshwater fishes

Ichthyobodo Pinto, 1928

Ichthyobodo necator (Henneguy, 1883) on the skin and gills of *Cyprinus carpio*, *Oreochromis mossambicus*, *Pseudocrenilabrus philander*, *Tilapia sparrmanii* [Fig. 4.2.5G]

Ichthyobodo sp. on the skin and gills of *Clarias gariepinus*, *Cyprinus carpio*, *Heterobranchus longifilis*, *Labeobarbus* sp., *Oreochromis niloticus*, *Synodontis schall*

Euglenozoa Cavalier-Smith, 1981 **– Metakinetoplastina** Vickerman in Moreira *et al.*, 2004

List of metakinetoplastins from African freshwater fishes

Cryptobia Leidy, 1846

Cryptobia iubilans Nohynková, 1948 in the stomach and intestine of *Clarias gariepinus*, *Heterobrachus longifilis*

Cryptobia sp. in the intestine, liver, gills and blood of *Clarias gariepinus*, *Coptodon rendalli*, *Enteromius paludinosus*, *Oreochromis niloticus*, *Sarotherodon galilaeus*, *Synodontis schall* [Fig. 4.2.5H]

Trypanosoma Gruby, 1843

Trypanosoma alhussaini Mohamed, 1978 from ***Clarias gariepinus*** (Egypt)

Trypanosoma cyanophilum Mohamed, 1978 from ***Coptodon zillii*** (Egypt)

Trypanosoma mansouri Mohamed, 1978 from ***Coptodon zillii*** (Egypt)

Trypanosoma cf. *mugilicola* Becker et Overstreet, 1979 from *Mugil cephalus*

Note: this fish inhabits marine, freshwater and brackish water systems.

Trypanosoma mukasai Hoare, 1932 from *Astatoreochromis alluaudi*, *Bagrus docmak*, *Clarias gariepinus*, *C. theodorae*, *Haplochromis cinereus*, *H. humilior*, *H. nubilus*, *H. serranus*, ***Haplochromis* spp**. (Uganda), *Mormyrus kannume*, *Oreochromis andersonii*, *O. esculentus*, *O. mossambicus*, *O. niloticus*, *O. variabilis*, *Parauchenoglanis ngamensis*, *Schilbe intermedius*, *Serranochromis angusticeps*, *S. macrocephalus*, *S. robustus*, *Synodontis nigromaculatus*, *S. vanderwaali*, *Tilapia sparrmanii* [Fig. 4.2.3D]

Trypanosoma tobeyi Dias, 1952 from ***Clarias angolensis*** (Mozambique)

Trypanosoma toddi Bouet, 1909 from *Clarias angolensis*, ***C. anguillaris*** (French West Africa)

Trypanosoma sp. from *Coptodon zillii* (Egypt)

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Chapter 4.3.
MYXOZOA

Ivan FIALA & Pavla BARTOŠOVÁ-SOJKOVÁ

Myxozoa – basic characteristics, life cycles, classification and principal diagnostic features

- parasitic cnidarians (Cnidaria: Myxozoa) with about 2,400 species classified in 67 genera with a worldwide distribution
- endoparasites of fish, annelids and bryozoans, less frequently in amphibians and reptiles; exceptionally in birds, mammals and sipunculids
- two-host life cycle: an invertebrate (annelid or bryozoan) definitive host produces actinospores or malacospores and a vertebrate (mostly fish) intermediate host produces myxospores or fish malacospores (Fig. 4.3.1)
- a vertebrate-derived spore consists mostly of two valves, 1-4 polar capsules and an infectious sporoplasm
- spores microscopic (typically 10-20 µm in size)
- spores develop in vegetative stages (trophozoites, plasmodia) which are histozoic (between tissue cells, *e.g.*, muscles, gills, skin, brain, kidney, liver and spleen) or coelozoic (in cavities, *e.g.*, gall bladder, urinary bladder, lumen of renal tubules and renal corpuscles)
- vegetative stages vary greatly in dimensions, histozoic ones may be macroscopic (up to several cm in diameter)
- trophozoites characterised by cell-within-cell organisation
- species belonging to *Myxobolus* are the most common freshwater myxozoans
- myxozoans from freshwater fishes cluster within the malacosporean clade (*Buddenbrockia*, *Tetracapsuloides*), *Sphaerospora* sensu stricto clade (*Sphaerospora*) and the freshwater (oligochaete) myxosporean lineage (all other genera, *e.g.*, *Myxobolus*).
- causative agents of serious fish diseases, *e.g.*, whirling disease and proliferative kidney disease (PKD)

The classification of the Myxozoa is based on myxospore morphology. The shape of the spore, number of shell valves and polar capsules and the position of the polar capsules within the spore are the most important features for the definition of myxozoan genera (Fiala *et al.* 2015; Fig. 4.3.2). Classification at the species level is based on other spore characteristics such as spore and polar capsule dimensions, spore surface structures, the number of polar filament coils, etc.

The subphylum Myxozoa consists of two classes, the Malacosporea (*Buddenbrockia* and *Tetracapsuloides*) and the Myxosporea with two orders, Bivalvulida and Multivalvulida (mostly marine species, *e.g.*, *Kudoa*). Bivalvulida includes two suborders: Variisporina (*e.g.*, *Myxidium*, *Zschokkella*, *Sphaerospora*, *Hoferellus*, *Chloromyxum* and *Myxobilatus*) and Platysporina (*e.g.*, *Myxobolus*, *Henneguya*, *Thelohanellus* and *Unicauda*) (Fig. 4.3.2).

Key to the genera of the Myxozoa from freshwater fishes (modified from Fiala *et al.* 2015)

The taxonomic key includes myxozoan genera reported from freshwater fishes from all continents (Lom & Dyková 2006) with the genera previously reported in Africa in bold.

1 (2) Spores with soft (unhardened) shell valves (Malacosporea)……3

2 (1) Spores with hardened shell valves (Myxosporea)…… 5

3 (4) Fish malacospores with two shell valves, two spherical polar capsules, one sporoplasm; bryozoan-related trophozoites sac- or worm-like; sacs irregularly shaped, elongate, ellipsoid or constricted; myxoworms with triploblast organisation……..*Buddenbrockia*

4 (3) Fish malacospores with two shell valves, two spherical polar capsules, one sporoplasm; bryozoan-related stages mostly sac-like of regular spherical shape……*Tetracapsuloides*

5 (6) Mature spore contains only one polar capsule……7

6 (5) Mature spore contains two or more polar capsules……11

7 (8) Spore with a bifurcate caudal process……*Phlogospora*

8 (7) Spore without a caudal process……9

9 (10) Spores with polar capsule discharging apically and axially [Fig. 4.3.2B] ……..***Thelohanellus***

10 (9) Spores with polar capsule discharging subapically and to the side ……..*Neothelohanellus*

11 (12) Mature spore contains two polar capsules……13

12 (11) Mature spore contains four or more polar capsules……51

13 (14) Polar capsules set apart from each other……15

14 (13) Polar capsules located close to each other……..25

15 (16) Polar capsules each located separately at spore ends……...17

16 (15) Polar capsules located not terminally and set widely apart in the sutural plane……...19

17 (18) Spores fusiform, straight or slightly crescent or sigmoid-shaped with more or less pointed ends, usually pyriform polar capsules; mostly coelozoic [Fig. 4.3.2K]……. ***Myxidium***

18 (17) Spores usually ellipsoidal, slightly bent or semicircular, with rounded or bluntly pointed ends and almost spherical polar capsules; mostly coelozoic [Fig. 4.3.2L]……. ***Zschokkella***

19 (20) Spores spherical or subspherical [Fig. 4.3.2F]…….***Ortholinea***

20 (19) Spores ovoid or triangular……... 21

21 (22) Spores triangular with rounded corners, flattened parallel to sutural plane, without projections [Fig. 4.3.2G]……***Triangula***

22 (21) Spores ovoid……..23

23 (24) Spores flattened parallel to the sutural plane without sutural markings …….. *Neomyxobolus*

24 (23) Spores spindle-shaped in sutural view with sutural markings along the posterior border…….*Cardimyxobolus*

25 (26) Spores asymmetrical with two caudal projections……*Hennegoides*

26 (25) Spores bilaterally symmetrical…….27

27 (28) Polar capsules at distance from the spore apex……. 29

28 (27) Polar capsules in the apex of the spore…….31

29 (30) Spindle-shaped spores with two spherical polar capsules positioned in tandem at a distance from the anterior end and two projections at both spore ends……..*Neohenneguya*

30 (29) Large spherical polar capsules in the centre of an oval spore in valvular view and with triangular shape in sutural view…….*Wardia*

31 (32) Polar capsules set in a plane perpendicular to the sutural line……33

32 (31) Polar capsules set in the sutural plane……..39

33 (34) Spores without projections……..35

34 (33) Spores with projections……37

35 (36) Spores spherical, subspherical or slightly elongate in the direction perpendicular to the sutural plane; mostly coelozoic in the excretory system [Fig 4.3.2E]……..***Sphaerospora***

36 (35) Spores pyriform or mitre-like with ridged valves…….*Acauda*

37 (38) Spores spindle-shaped, with a pair of long posterior projections [Fig. 4.3.2I] ……..***Myxobilatus***

38 (37) Spores pointed, mitre-like or rounded in valvular view with numerous stiff filaments at the posterior end [Fig. 4.3.2J]…….***Hoferellus***

39 (40) Spores without projections……...41

40 (39) Spores with projections……43

41 (42) Sutural line strongly sinuous……..*Spirosuturia*

42 (41) Sutural line straight, spores ellipsoidal, ovoid or rounded [Fig. 4.3.2A] …… ***Myxobolus***

43 (44) Spores with a single caudal projection [Fig. 4.3.2C]……..…***Unicauda***

44 (43) Spores with more than one caudal projection……45

45 (46) Spores with two caudal projections……47

46 (45) Spores with four posterolateral projections……..*Tetrauronema*

47 (48) Spores with two laterally extending projections……49

48 (47) Spores with two slightly divergent projections [Fig. 4.3.2D]…..***Henneguya***

49 (50) Lateral projections extend from one side of the posterior spore end ……*Laterocaudata*

50 (49) Lateral projections extend in opposite directions……...*Dicauda*

51 (52) Spores with two shell valves……53

52 (51) Spores with four shell valves…….. 55

53 (54) Spores spherical [Fig. 4.3.2H]……..***Chloromyxum***

54 (53) Spores almost spherical with one or two caudal projections…… *Caudomyxum*

55 (56) Spores stout spindle-shaped with the sutural ridge extending both spore ends as a spine, coelozoic…… *Octospina*

56 (55) Spores stellate, quadrate, subspherical to ovoid in apical view; histozoic [Fig. 4.3.2M]…….……..***Kudoa***

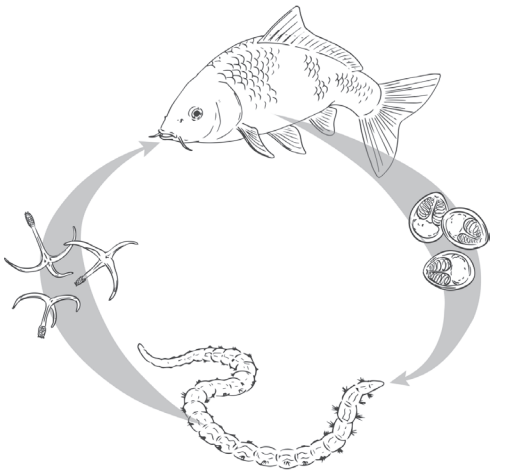

Fig. 4.3.1. Myxozoan life cycle with an annelid definitive host releasing actinospores and a fish intermediate host releasing myxospores. (Illustration by M. Luo.)

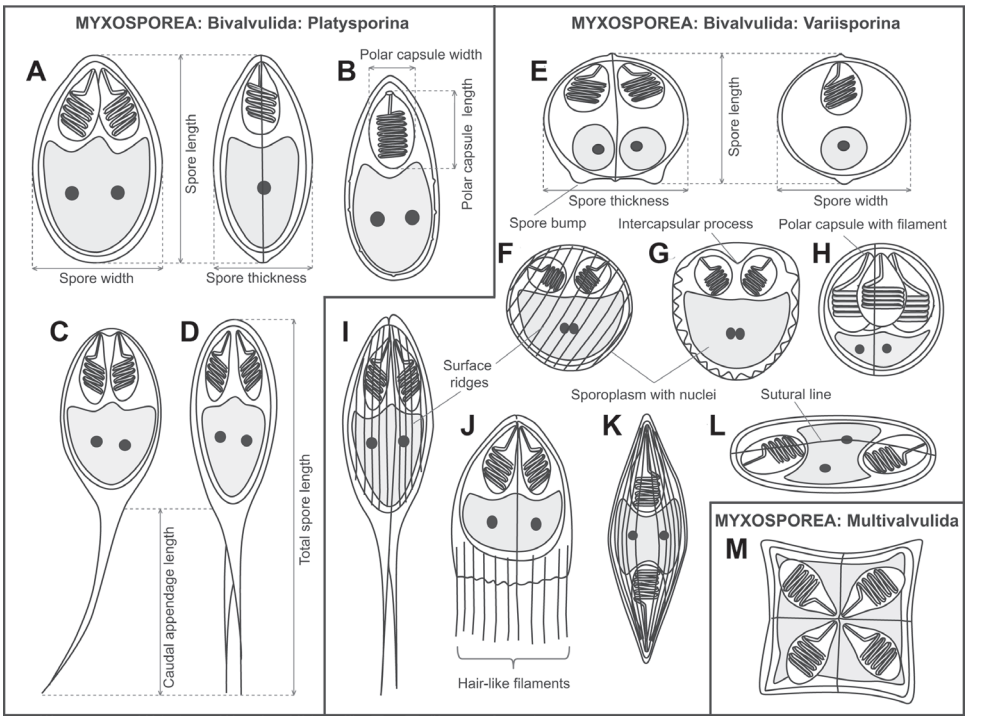

Fig. 4.3.2. Schematic line drawings of myxospores representing myxosporean genera reported from African freshwater fishes with instructions on spore measurements and indicating the most important spore features. **A.** *Myxobolus*, frontal and sutural view; **B.** *Thelohanellus*; **C.** *Unicauda*; **D.** *Henneguya*; **E.** *Sphaerospora*, sutural and lateral view; **F.** *Ortholinea*; **G.** *Triangula*; **H.** *Chloromyxum*; **I.** *Myxobilatus*; **J.** *Hoferellus*; **K.** *Myxidium*; **L.** *Zschokkella*; **M.** *Kudoa*.

List of the Myxozoa in African freshwater fishes

Species are listed alphabetically according to individual myxozoan genera with information about infection site and type host species (in bold) and country of origin if described from Africa. The systematic survey is based on Fomena & Bouix (1997), Eiras (2002), Eiras *et al.* (2005, 2011, 2012, 2014), Abdel-Ghaffar *et al.* (2008), Eiras & Adriano (2012), Zhang *et al.* (2013), and Alama-Bermejo *et al.* (2016).

Cnidaria Hatschek, 1888

MYXOZOA Grassé, 1970

Myxosporea Bütschli, 1881

Bivalvulida Shulman, 1959

PLATYSPORINA Kudo, 1919

Henneguya Thélohan, 1892

Henneguya auchenoglanii Kostoïngué, Diebakate, Faye et Toguebaye, 2001 in the base of primary gill lamellae of ***Auchenoglanis occidentalis*** (Chad)

Henneguya bopeleti Fomena et Bouix, 1987 in the gills of ***Chrysichthys nigrodigitatus*** (Cameroon)

Henneguya branchialis Ashmawy, Abu-Elwafa, Imam et El-Otifi, 1989 in the gills and intestine of *Clarias anguillaris*, ***C. gariepinus*** (Egypt), *Coptodon zillii*, *Sarotherodon galilaeus*

Henneguya camerounensis Fomena et Bouix, 1987 in the gills of *Schilbe multitaeniatus*, ***Synodontis batesii*** (Cameroon)

Henneguya chrysichthyi Obiekezie et Enyenihi, 1988 in the gills of ***Chrysichthys nigrodigitatus*** (Nigeria)

Henneguya clariae Abolarin, 1971 in the gills of ***Clarias gariepinus*** (Nigeria)

Henneguya ctenopomae Fomena et Bouix, 1996 in the gills of ***Microctenopoma nanum*** (Cameroon)

Henneguya dini Kabre, Sakiti, Marquès et Sawadogo, 1997 in the gills of ***Heterotis niloticus*** (Burkina Faso)

Henneguya fusiformis Kostoïngué, Fall, Faye et Toguebaye, 1999 in the gills of ***Clarias anguillaris*** (Chad), *C. gariepinus*.

Henneguya ghaffari Ali, 1999 in the intestine, pyloric caeca and gills of ***Lates niloticus*** (Egypt)

Henneguya laterocapsulata Landsberg, 1987 in the skin of *Clarias gariepinus*, ***C. gariepinus*** × ***Heterobranchus bidorsalis***