Introduction

For sustainable development, the challenge for the Mekong countries is how to develop and improve economic conditions while maintaining the biodiversity and ecological health of the river. Assessing and monitoring surface water quality are essential activities that will help to prevent increasing water pollution and to protect aquatic life and human health. Bioassessment provides one the best tools for monitoring and assessing the ecological health of rivers, and benthic macroinvertebrates are the group of organisms used most frequently to measure pollution in running water (Hellawell, 1986; Abel, 1966; Metcafe, 1989; Rosenberg & Resh, 1993 and references therein). The term benthic macroinvertebrates refers organisms that inhabit the bottom substrates of any freshwater habitat for at least part of their life cycle. Macroinvertebrates have a body length of more than 0.5 mm, and will be retained by a net with a 200 µm mesh. The advantages of benthic macroinvertebrates were summarised in Rosenberg & Resh (1993). First, they have high diversity, high abundance and wide distribution; so they can be affected by environmental disturbance in different types of aquatic systems. Second, they are diverse in form and have a wide range of sensitivity to many kinds of anthropogenic changes and stresses. Third, their sedentary nature and long life facilitates both analysis of spatial and temporal changes caused by environmental perturbations in aquatic systems and bioaccumulation studies. In this regards, benthic macroinvertebrates provide a means for continuous monitoring, because they respond to both short- and long-term changes to the water they inhabit. Their size is big enough to be observed by the naked eye or with the aid of a hand lens. In addition, sampling techniques and methods of data analysis are well established and their taxonomy is well defined (Humphrey & Dastine, 1994).

Reliable biomonitoring demands accurate and consistent identification of invertebrates to a taxonomic level that is practical, particularly in the field. The keys in this study were constructed to aid the identification of benthic macroinvertebrates of the Mekong River and its tributaries in the four MRC member countries (Cambodia, Lao PDR, Thailand, and Viet Nam). Zooplankton or microscopic forms are not considered. These keys were devised by consulting all available keys to North American, British and Asian invertebrate faunas. In addition, the many publications on genera and species that comprise the biota of the region (such as crabs, shrimps, aquatic insects and molluscs) provided essential supplementary information.

Chapter 1 of this book, contains a key of benthic macroinvertebrates to the higher taxonomic levels of phylum, class, and order. The subsequent chapters provide information on the general structure and function of each phylum, followed by a key to family, genus or species level. In the case of the phylum Mollusca, gastropods (snails) are separated from pelecypods (bivalves). Likewise, arthropods are so diverse that the crustaceans and aquatic and semiaquatic insects were separated and given their own chapters. These are then followed by keys to order, family, genus or species level. Illustrations of important morphologic characters are provided to help aid identification. Most figures were illustrated from archived specimens at Khon Kaen University, or from loaned specimens. Any unavailable specimens or characteristics were redrawn from available publications.

For most of the benthic macroinvertebrates groups, the keys stop at family level. However, keys to generic or specific level are given for some groups, such as freshwater crabs and shrimps, and some insect orders (Ephemeroptera, Plecoptera, Hemiptera, and some families of Trichoptera and Diptera).

An index is included for locating taxa in the text and keys and for those taxa that are illustrated. A glossary is provided to help explain some of the terminology used in the keys.

Chapter 1 Major Groups of Freshwater Invertebrates

The International Code of Zoological Nomenclature (ICZN) defines a hierarchical classification system of the animal kingdom. The five principal taxonomic levels of the system are:

Phylum
- Class
  - Order
    - Family
      - Genus
        - Species

The ‘species′ is the basic taxonomic rank. When it is first described, each species is assigned a name comprising two parts, a generic name and a specific name. In the example of the biological name for humans, *Homo sapiens*, *Homo* is the generic name, and *sapiens* is the specific name. A genus includes related species, and many related genera are classified into families, and so on up the hierarchy. As a result, every description of a new species also implicitly places the species in the taxonomic hierarchy, thereby defining its place in the animal kingdom and how it relates to other species.

Two other groupings have become widely recognised: cohort and tribe. ‘Cohort′ is interposed between class and order, and ‘tribe′ between family and genus. However, this still is not sufficient to meet the needs of taxonomists. The addition of prefixes (sub or super) to the name of the taxon was introduced to increase categories in the classification system. For example, the genera in a family may be grouped in a number of subfamilies, and the family may in turn be a member of a superfamily. And more recently the prefix infra- was introduced for groups below the subgrouping.

However, the term ‘invertebrate′ does not imply any biological affinities, but rather is a lose grouping used by zoologists historically to include all multi-cellular animals without backbones. The major groups of invertebrates in this book are listed as follows[1]:

Phylum Porifera
- Class Demospongiae
  - Order Haploclerina
    - Family Spongillidae

Phylum Cnidaria
- Class Hydrozoa
  - Order Hydroida
    - Family Hydridae
  - Order Trachylina
    - Family Petasidae

1 * no further discussion; a = plankton; b = insufficient information; c = occurs only in temporary ponds

Phylum Platyhelminthes
- Class Turbellaria
  - Order Tricladida
    - Family Planariidae

Phylum Rotifera*a

Phylum Nematoda*b

Phylum Nematomorpha*b

Phylum Bryozoa (Ectoprocta)
- Class Phylactolaemata
    - Family Lophopodidae
    - Family Fredericellidae
    - Family Plumatellidae

Phylum Annelida
- Class Polychaeta*b
- Class Oligochaeta*b
- Class Hirudinea
  - Order Rhynchobdellida
    - Family Glossiphoniidae
    - Family Piscicolidae
  - Order Gnathobdellida
    - Family Hirudinidae
  - Order Pharyngobdellida
    - Family Erpobdellidae

Phylum Mollusca
- Class Gastropoda
- Subclass Prosobranchia
  - Order Mesogastropoda
    - Family Bityniidae
    - Family Hydrobiidae
    - Family Pilidae (Ampullariidae)
    - Family Stenothyridae
    - Family Thiaridae
    - Family Viviparidae
  - Order Neogastropoda
    - Family Buccidae
- Subclass Pulmonata
  - Order Basematophora
    - Family Ancylidae

        - Family Lymnaeidae
        - Family Planorbidae
- Class Pelecypoda
- Subclass Heterodonta
    - Order Veneroida
        - Family Corbiculidae
        - Family Dreissenidae
        - Family Sphaeriidae
- Subclass Pteriomorpha
    - Order Arcoida
        - Family Arcidae
    - Order Mytiloida
        - Family Mytilidae
- Subclass Schizodontida
    - Order Unionoida
        - Family Amblemidae

Phylum Arthropoda

Subphylum Chelicerata

- Class Arachnida
    - Order Araneae
        - Family Agelenidae
    - Order Acarina[*b]

Subphylum Crustacea

- Subclass Branchiopoda
    - Order Anostraca[c]
        - Family Streptocephalidae
    - Order Conchostraca[*c]
    - Order Notostraca [*c]
    - Order Cladocera [*a]
- Subclass Copepoda
    - Order Eucopepoda [*a]
    - Order Branchiura
        - Family Argulidae
- Subclass Ostracoda [*b]
- Subclass Malacostraca
    - Order Isopoda [*b]
    - Order Amphipoda
        - Family Gammaridae

Order Decapoda

Family Atyidae

Family Palaemonidae

Family Parathelphusidae

Family Potamidae

Family Gecarcinucidae

Subphylum Uniramia

Class Insecta

Subclass Apterygota

Order Collembola

Family Isotomidae

Subclass Pterygota

Order Ephemeroptera

Family Baetidae

Family Behningiidae

Family Caenidae

Family Ephemerellidae

Family Ephemeridae

Family Euthyplocidae

Family Heptageniidae

Family Isonychidae

Family Leptophlebiidae

Family Neoephemeridae

Family Oligoneuriidae

Family Palingeniidae

Family Polymitarcyidae

Family Potamanthidae

Family Prosopistomatidae

Family Teloganellidae

Family Teloganodidae

Family Vietnamellidae

Order Odonata

Suborder Zygoptera

Family Amphipterygidae

Family Calopterygidae

Family Chlorocyphidae

Family Coenagrionidae

Family Euphaeidae

Family Lestidae
Family Megapodagrionidae
Family Platycnemididae
Family Platystictidae
Family Protoneuridae
Suborder Anisoptera
Family Aeshnidae
Family Cordulegastridae
Family Corduliidae
Family Gomphidae
Family Libellulidae
Order Orthoptera
Family Acrididae
Family Blaberidae
Family Gryllidae
Family Gryllotalpidae
Family Tetrigidae
Family Tettigoniidae
Family Tridactylidae
Order Plecoptera
Family Leuctridae
Family Nemouridae
Family Peltoperlidae
Family Perlidae
Order Hemiptera (Suborder Heteroptera)
Infraorder Nepomorpha
Family Aphelocheiridae
Family Belostomatidae
Family Corixidae
Family Gelastocoridae
Family Helotrephidae
Family Micronectidae
Family Naucoridae
Family Nepidae
Family Notonectidae
Family Ochteridae
Family Pleidae
Infraorder Gerromorpha

Family Gerridae
Family Hebridae
Family Hydrometridae
Family Mesoveliidae
Family Veliidae
Infraorder Leptopodomorpha
Family Leptopodidae
Family Saldidae
Order Megaloptera
Family Corydalidae
Family Sialidae
Order Neuroptera[*b]
Order Trichoptera
Suborder Spicipalpia
Family Glossosomatidae
Family Hydrobiosidae
Family Hydroptilidae
Family Rhyacophilidae
Suborder Annulipalpia
Family Dipseudopsidae
Family Ecnomidae
Family Hydropsychidae
Family Philopotamidae
Family Polycentropodidae
Family Psychomyiidae
Family Stenopsychidae
Family Xiphocentronidae
Suborder Integripalpia
Family Apataniidae
Family Beraeidae
Family Brachycentridae
Family Calamoceratidae
Family Goeridae
Family Helicopsychidae
Family Lepidostomatidae
Family Leptoceridae
Family Limnephilidae
Family Limnocentropodidae

Family Molannidae
Family Odontoceridae
Family Phryganeidae
Family Phryganopsychidae
Family Sericostomatidae
Family Uenoidae
Order Lepidoptera
Family Crambidae
Order Coleoptera
Suborder Adephaga
Family Amphizoidae
Family Carabidae
Family Dytiscidae
Family Gyrinidae
Family Haliplidae
Family Hygrobiidae
Family Noteridae
Suborder Polyphaga
Family Chrysomelidae
Family Curculionidae
Family Dryopidae
Family Elmidae
Family Hydraenidae
Family Hydrochidae
Family Hydrophilidae
Family Hydroscaphidae
Family Lampyridae
Family Psephenidae
Family Ptilodactylidae
Family Scirtidae
Family Staphylinidae
Order Hymenoptera
Family Agriotypidae
Order Diptera
Suborder Nematocera
Family Blephariceridae
Family Ceratopogonidae
Family Chaoboridae

Family Chironomidae
Family Culicidae
Family Dixidae
Family Psychodidae
Family Simuliidae
Family Tipulidae
Suborder Brachycera
Family Athericidae
Family Empididae
Family Ephydridae
Family Stratiomyidae
Family Syrphidae
Family Tabanidae

Classification

Phylum Porifera

Nearly all of the 10,000 known species of sponges are marine forms, only about 100 species live in freshwater. All freshwater sponges belong to one family, Spongillidae in the order Haploclerina. They are usually found in clean water, and are found attached to any firm permanent substrates, such as rocks, submerged snags, shells of bivalves or man-made hard surfaces. The body of freshwater sponges is supported by spicules and has a leuconoid water canal system. A colony is easy to recognise because it is perforated by numerous small pores and a few large ones. Sponges produce a dormant structure called a gemmule which is resistant to unfavourable environmental conditions.

Phylum Cnidaria

The cnidarians are diverse and abundant in the sea, and they include jelly fishes, sea anemones and corals. Only a few genera in the class Hydrozoa occur in freshwater. They have two forms: sessile polyps, and free-swimming medusae. All cnidarians have radial symmetry and possess diploblastic bodies (the epidermis and the gastrodermis have mesoglea in between). Cnidarians have tiny, stinging organelles, called nematocysts, for capturing prey and defending themselves. Nematocysts are embedded in the body wall and are especially abundant on the tentacles. The nematocysts may be specialized for wrapping around small prey, sticking to surfaces, penetrating surface, or secreting toxin. The polyp form, or hydra, is a common cnidarian found attached to substrates in slowly moving water. The medusa form, or jelly fish, is rare in freshwater. All freshwater cnidarians are carnivorous and feed on small invertebrates such as water fleas and mosquitoes larvae.

Phylum Platyhelminthes

The platyhelminths include one primitive class of mostly free-living individuals (Class Turbellaria) and two classes of exclusively parasitic individuals (Class Trematoda and Class Cestoda). They are acoelomate, triploblastic and bilaterally symmetrical. The most well known free-living turbellarian is a triclad in the family Planariidae. Planarians are mainly carnivorous, feeding largely on small invertebrates. They use their anterior end to wrap around prey and then they extend the proboscis to ingest the body tissue of the prey. They usually glide around on rocks and debris in both running and standing waters.

Phylum Nematoda and Phylum Nematomorpha

The Nematoda and Nematomorpha are pseudocoelomate animals. Free-living nematodes in freshwater are tiny and can be recognized by their spindle shape. Nematomorpha, or horse-hair worms, are much larger and long and slender. Juveniles are parasitic in arthropods but adults are free-living. Adults do not feed; they live in freshwater habitats or in any wet or moist surroundings, surviving only long enough to reproduce.

Phylum Rotifera

Rotifers are tiny worm-like pseudocoelomates, ranging in size from 25 µm to 20 mm. The body is divided into three or four distinct regions: head, neck, trunk and foot. In some species the trunk is enclosed by a hardened lorica. The head bears a wheel organ called the corona. The rotifer is a filter-feeder; the cilia of the corona provides locomotory and feeding currents. The head is usually retracted into the trunk. Food particles enter the mouth to be ground up in the mastax before passing to the stomach where digestion occurs. Undigested food is expelled through the anus. Most rotifers are found in ephemeral ponds or rivers. They serve as a natural food for fishes and are also important aquaculture feed. They produce eggs, but most eggs develop without being fertilized (through parthenogenesis), and there are no males in some species.

Phylum Bryozoa

Bryozoans, or moss animals, are coelomate, colonial, sessile, lophophorate, filter feeders, usually fixed to a hard substrate. The colony consists of fine branching tubes with a plant-like growth form. Colonies are found on submerged substrate or on the underside of floating debris. Zygotes develop into free-swimming larvae which settle onto the substrate and begin budding zooids to form new colonies. Freshwater bryozoans produce resistant bodies called statoblasts. During dry seasons, most bryozoans die but the statoblasts remain viable. When the favourable conditions return, they hatch out and begin budding to form new colonies.

Phylum Mollusca

The phylum Mollusca is one of the largest animal phyla. Almost all molluscs have calcareous shells which are secreted by the mantle. Most molluscs have a foot, which is highly modified for a variety of functions in different groups. They have a true coelom, an open circulatory system and exchange gas across the gills, lungs, mantle or the body surface.

Phylum Mollusca contains six classes, but only two are found in freshwater—Gastropoda and Pelecypoda. These two classes are economically important, and many of the gastropods are intermediate hosts of animal parasites.

Phylum Annelida

Freshwater oligochaetes and freshwater leeches are members of the phylum Annelida. They are worm-like, with metamerically segmented bodies and a true coelom. The body wall is soft and covered with a cuticle. The circulatory system is closed, and gas exchange occurs across the skin and gills. Freshwater oligochaetes are small, long and slender worms. They usually crawl on the bottom or burrow into the soft mud. Mostly oligochaetes are free-living, and feed on algae and detritus. They are an important food source for fishes.

Freshwater leeches are members of class Hirudinea. They have a fixed number of segments, usually 34, and typically they have both an anterior and a posterior sucker. Many leeches are carnivores on small invertebrates; some are parasite, sucking blood from vertebrate hosts.

Phylum Arthropoda

Arthropoda is the most diverse phylum of animals. They compose at least 75% of all known animal species on Earth. The body is covered with an exoskeleton secreted by epidermal cells. The exoskeleton is mainly chitinous and functions as protection, support and an aid to movement. It is hard and rigid, and is moulted at intervals to allow the animal to increase its body size. Body segments are grouped into tagmata such as the head and trunk, or the head, thorax and abdomen. Arthropods bear jointed appendages that are modified for specialized functions. The nervous, muscular, and respiratory systems are well developed. The body cavity is reduced to a hemocoel in the open circulatory system. Arthropods have successfully colonised all types of habitats. Freshwater arthropods include shrimps, crabs, water fleas, ostracods, isopods, amphipods, aquatic and semiaquatic insects, water spiders and water mites. Insects are the major component of macroinvertebrates in running water. Arthropods are a natural food source for large invertebrates and fishes. They are also used for human food and they have high economic value. Some aquatic insects are sensitive to environmental changes while others are very tolerant. Many are used as bio-indicators of water quality or environmental assessment.

The following key is to the phyla, classes and orders of major freshwater invertebrates. Keys to lower taxonomic levels of each phylum are available in following chapters.

Key to Phyla, Classes and Orders of Major Freshwater Invertebrates

1 Body enclosed by a calcareous shell (Fig. 1, 2) ....Phylum Mollusca (snails, clams, mussels) 2 (p. 41)
1′ Body not enclosed in a calcareous shell 3

2(1) Body in a single shell (Fig. 1) .... Class Gastropoda (p. 54)
2′ Body in two shell (Fig. 2) .... Class Pelycypoda (p. 67)

3(1) Segmented body 10
3′ Unsegmented body 4

4(3′) Colonial animal covering the surface of submerged objects such as rocks, logs, twigs and plants, or on floating materials 5
4′ Animals not sessile 6

5(4) Colony form a rough mat with pores on the surface (Fig. 3a); skeleton composed of spicules (Fig. 3b): gemmule formation usually occurs (Fig. 3c); colony found only on stable submerged objects ....Phylum Porifera, (p. 19) Class Demospongiae (freshwater sponges)
5′ Colony form a thin layer on both stable and floating materials (Fig. 4a); animals with a lophophore (Fig. 4b) ....Phylum Bryozoa, (p. 33) (moss animals)

6(4′) With radial symmetry, with nematocysts particularly on tentacles (Fig. 5b); polyp form attached to substrates (Fig. 5a), medusa form floating (Fig.6) .... Phylum Cnidaria, (p. 23) Class Hydrozoa (Hydras, freshwater jelly fish)
6′ With bilateral symmetry 7

7(6′) Size usually between 100 and 500 µm; anterior end with disc-like, with corona (Fig. 7); body shape ranges from spherical to linear, body divided into 3 regions: head, trunk and foot (Fig. 7) ....Phylum Rotifera (p. 27)
7′ Larger size, visible to naked eye.. 8

8(7′) Elongate flattened body; anterior part with a pair of eyespots; proboscis on ventral side of body (Fig. 8); gliding movement on rock surface or among wood debris...... ....Phylum Platyhelminthes, (p. 25) Class Turbellaria (flatworms, planaria)
8′ Body not flattened.. 9

9(8′) Length less than 5 cm; spindle-shaped and transparent (Fig. 9) .... Phylum Nematoda (p. 29)

9′ Length more than 5 cm; thread-like; anterior and posterior end rounded; often coiled (Fig. 10):brown colour..................................Phylum Nematomorpha (p. 31)

10(3) Body with obvious jointed legs ....Phylum Arthropoda...14 (p. 75)

10′ Body without obvious jointed legs 11

11(10′) Body with some jointed appendages (Fig. 11) .... Class Insecta (pupae or dipteran larvae)

11′ Body with no jointed appendages (Fig. 12,13)...........Phylum Annelida...12 (p. 37)

12(11′) With anterior and posterior suckers (Fig. 12); body without setae.......................... .... Class Hirudinea (leeches) (p. 38)

12′ Without suckers; body worm-like... 13

13(12′) Body without lateral appendages; segments with fine setae ....(Fig. 13) Class Oligochaeta

13′ Body with lateral appendages, segments with long setae.............Class Polychaeta

14(10) With 3 pairs of jointed legs; one pair of antenna.. ....Subphylum Uniramia, Class Insecta

14′ With more than 3 pairs of jointed legs; either no antenna or 2 pairs of antennae .. 15

15(14′) Four pairs of jointed legs; lacking antennae... ....Subphylum Chelicerata, Class Arachnida...16

15′ More than 4 pairs of jointed legs; with 2 pairs of antennae .... Subphylum Crustacea (p. 79)

16(15) Body with two sections - prosoma and opisthosoma (Fig. 14)................................ ....Order Araneae (water spiders)

16′ Body with one section (Fig. 15) .... Order Acarina (water mites)

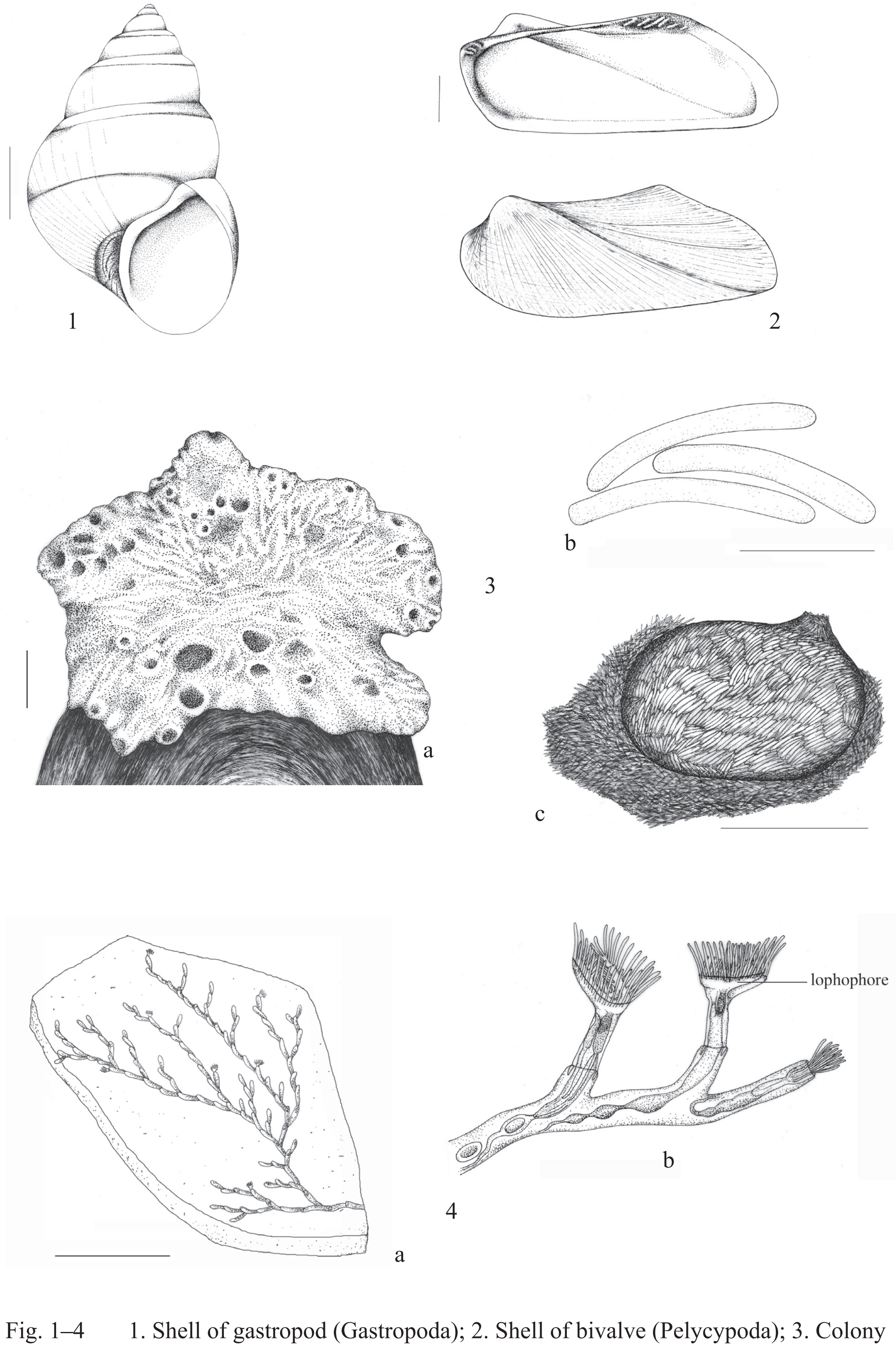


Fig. 1–4 1. Shell of gastropod (Gastropoda); 2. Shell of bivalve (Pelycypoda); 3. Colony form (a), spicule (b) and gemmule (c) of freshwater sponges; 4. Colonial form (a) and zooid (b) of freshwater bryozoan.
Scale: (3a) 5 mm; (1,2,4a) 1 mm, (3b,3c) 0.5 mm.

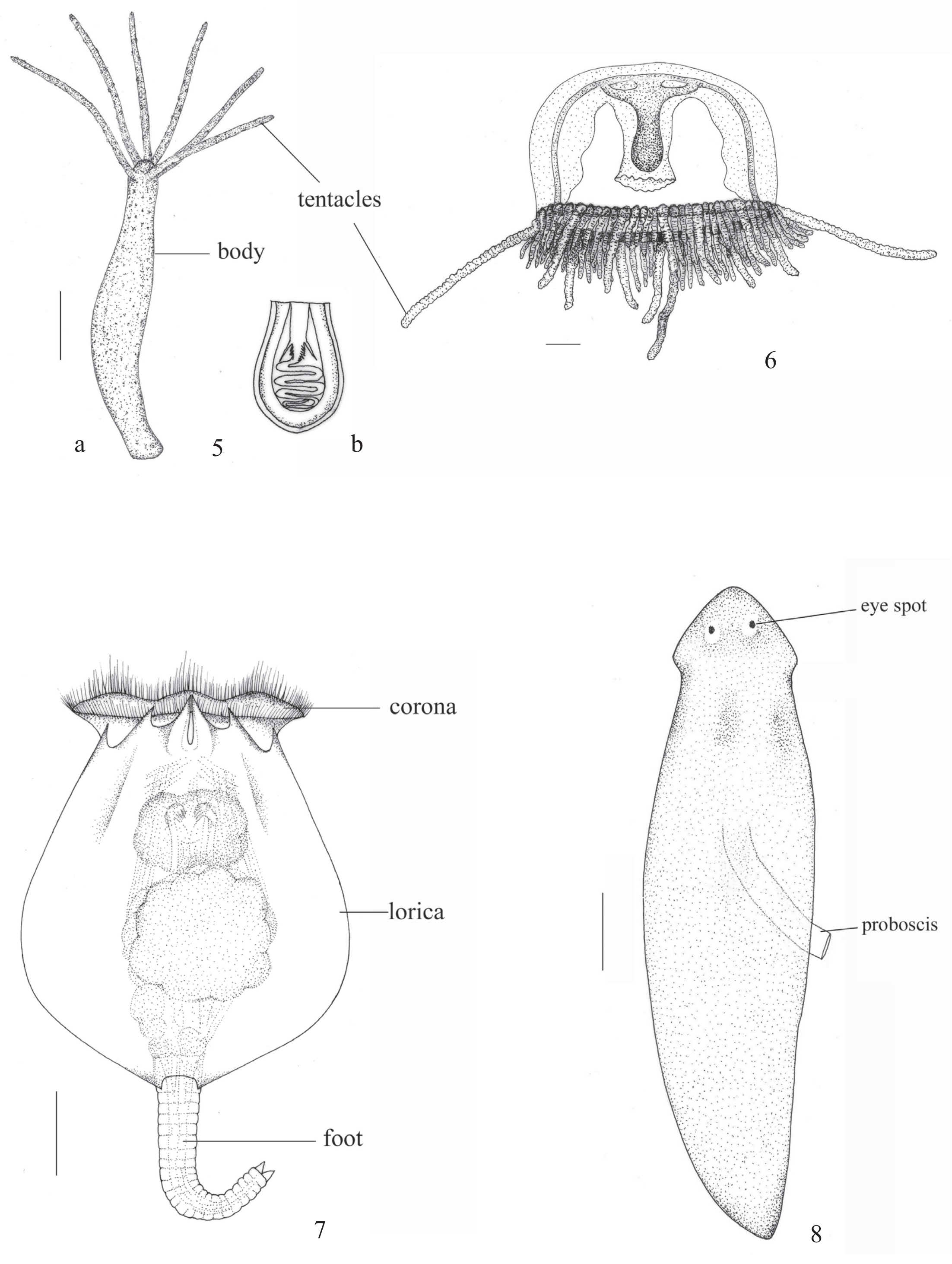
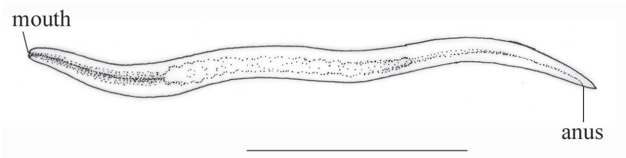


Fig. 5–8. 5. Structure of hydra (a) and nematocyst (b); 6. Freshwater jelly fish; 7. Structure of *Brachionus rubens* (Rotifera); 8. Dorsal view of planarian (Turbellaria).
Scale: (6) 2 mm; (5,8) 1 mm, (7) 50 µm.



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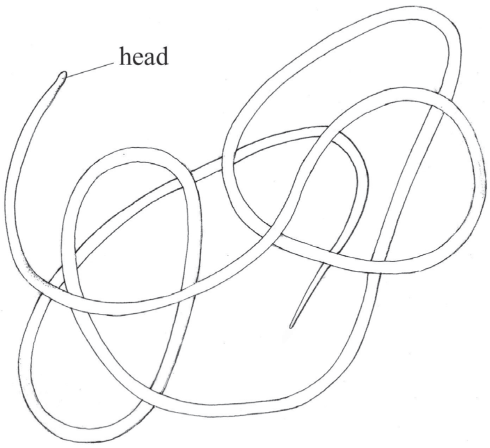

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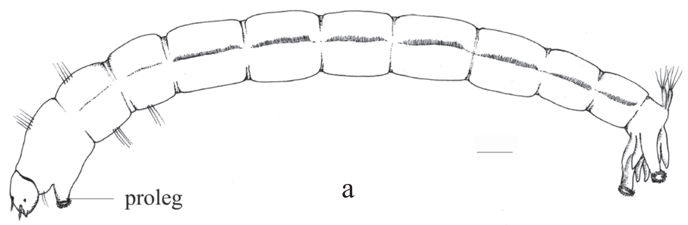

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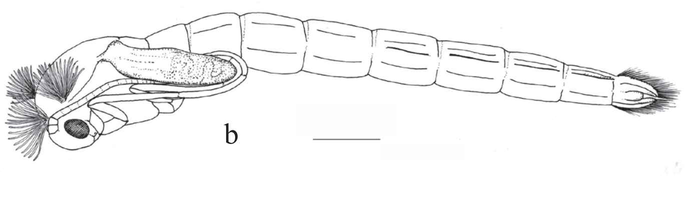
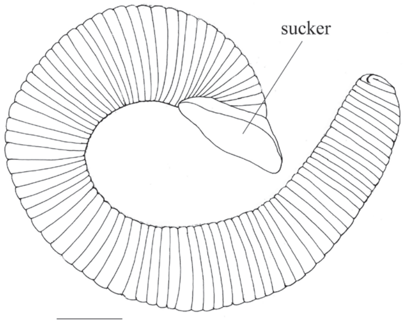


Fig. 9–11 9. Structure of nematode (Nematoda); 10. Structure of horsehair worms (Nematomorpha); 11. Side view of chironomid larva (a) and pupa (b) (Chironomidae).
Scale: (10,11a-b) 1 mm; (9) 0.5 mm.



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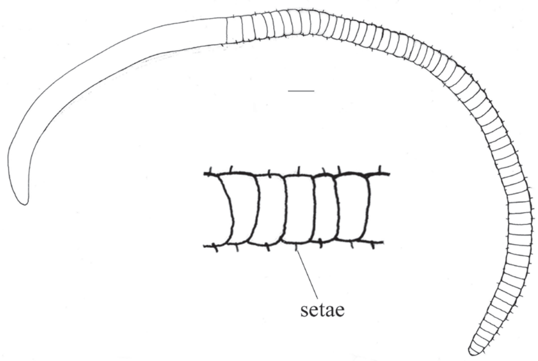

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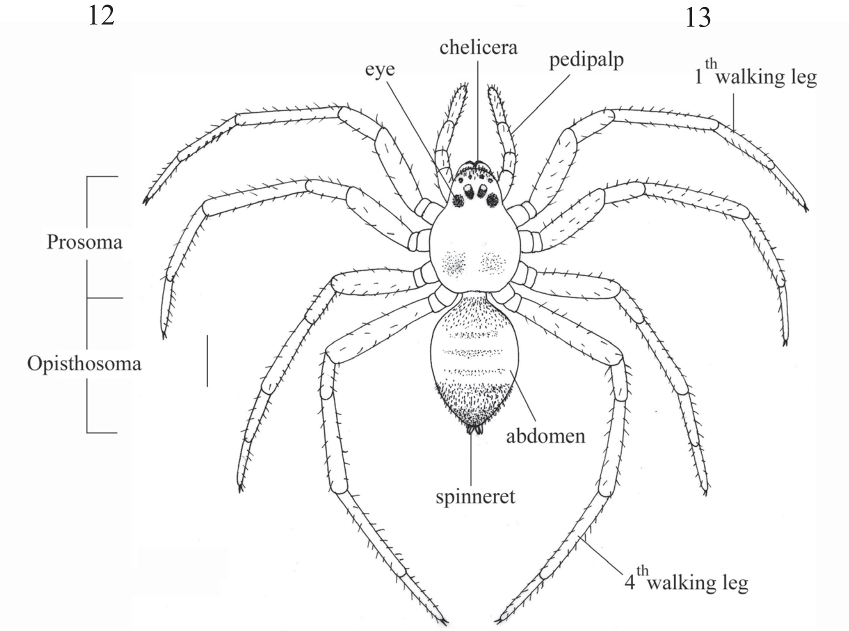

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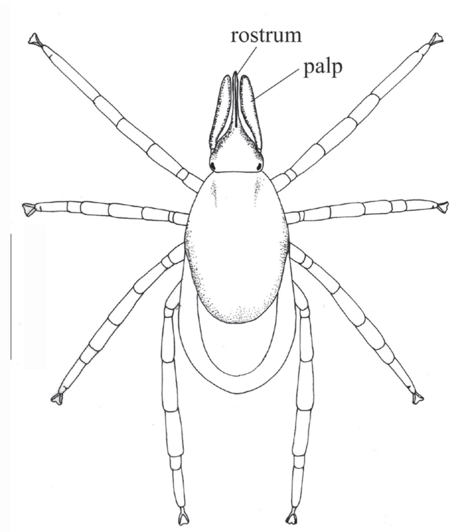

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Fig. 12–15 12. Side view of leech (Hirudinea); 13. Side view of oligochaetes (Oligochaeta); 14. Dorsal view of spiders (Araneae); 15. Dorsal view of water mites (Acarina). Scale: (12) 5 mm; (13,14,15) 1 mm.

Chapter 2 Phylum Porifera

Sponges are multicellular animals with a **cellular level** of organization. They have no tissue or organs. The body is a loose aggregation of mesenchymal cells, and has either radial symmetry or asymmetry. The body is perforated with many tiny incurrent water pores (ostia) and few larger excurrent pores (osculum) (Fig. 1a). The pores are connected to **canal systems**. The epidermis consists of flat pinacocytes and the inner surface is lined with flagellated collar cells (**choanocytes**). In the simplest sponges the large cavity, which is lined with choanocytes, is called the spongocoel. Between pinacocytes and the choanocyte layer is the **mesohyl**, or gelatinous protein matrix, which contains amoebocytes, collocytes and skeleton structures. The skeletal structures are calcareous or siliceous **spicules** or protein collagen fibers (**spongin fiber**). The skeleton of freshwater sponges is made of siliceous spicules (Fig. 1b, 2).

General structure and function

There are three levels of sponge construction based on the canal system: asconoid, syconoid and leuconoid (Fig. 3-5), in order of increasing amount of surface area available for food collection.

The **asconoid** sponges are small and cylindrical shaped. Water enters through ostia into a large spongocoel (Fig. 3). The choanocyte flagella pull the water through the pores and expel it through an osculum.

The **syconoid** sponges are tube-shaped and have a single osculum, but the body wall is thicker and more complex than that of asconoids. Water enters through ostia into incurrent canals which bring it to the choanocyte-lined radial canals (flagellated canal), which then empty into the spongocoel. The spongocoel is lined with epithelial cells other than the choanocytes (Fig. 4).

The **leuconoid** type is the most complex sponge. Unlike asconoid and synconoid sponges, which are small sponges, the leuconoid sponges are adapted for increase in size and they usually form large colonial masses. Each colony has one ostium. Water goes through incurrent canals into flagellated chambers (lined with choanocytes) and is discharged into the excurrent canal before leaving through the osculum (Fig. 5).

Sponges have no digestive system. The flagella of the choanocytes beat to pull water through the sieve-like collar and force it out through the open top of the collar. Large particles that can not enter the collar will be trapped by secreted mucus from collar cells and are phagocytized by the cell body. The engulfed food is passed on to the archeocytes (originated from amoebocyte) for intracellular digestion. Digested foods are stored in archeocytes and transferred to other cells by diffusion and amoebocytotic transport.

Gas exchange and water-soluble waste products diffuse into the water surrounding the sponge. Water-insoluble wastes are given off by amoebocytes into the excurrent canals.

Some sponges are monoecious (having both male and female in one individual), and some are dioecious (having separate sexes). All sponges reproduce sexually and asexually. Internal fertilization takes place in the mesohyl, where ova are fertilized by motile sperms. The zygotes develop into flagellated larvae and are released from the parent. Larvae swim for a period of time before setting on the substrate and metamorphosing into the sessile young sponges. Sponges reproduce asexually by forming external buds that remain attached, to form colonies. Freshwater sponges and some marine sponges reproduce asexually by producing the highly resistant resting stages called **gemmules** (Fig. 2). The gemmule is a spherical structure with a dead, secreted outer layer, a covering of spicules and an internal mass of live archeocytes. The gemmules can survive a period of drought, and germinate in favourable conditions. The micropyle opens and the archeocytes in the gemmule escape to develop into a new sponge.

Ecological relationships and economic importance in the region

Most sponges are marine and often found on coral reefs. Sponges are host to many commensal or parasitic organisms. Some marine crabs attach pieces of sponge to their carapace for camouflage and protection.

Freshwater sponges have no economic value. They can grow over the nets of fish culture cages and obstruct water flow through the net.

Classification

Sponges are grouped into four classes, based largely on the chemical composition and morphology of the skeletal elements: Calcarea, Hexactinellida, Demospongiae and Sclerospongiae.

Class Calcarea

Calcarea have calcium carbonate spicules and are tubular or vase-shaped. Their structure may be asconoid, syconoid or leuconoid. All are marine.

Class Hexactinellida

Glass sponges are found in the deep sea. They bear six-rayed siliceous spicules bound together as a latticework. The canal systems may be syconoid or leuconoid and the outer layer is syncytial (having many nuclei contain in a single plasma membrane).

Class Demospongiae

Almost 80% of sponge species are in Demospongiae. They have a leuconoid canal system, and the skeleton may be of siliceous spicules, spongin fibers or both. All are marine forms, except for the family Spongillidae which is found in freshwater. Freshwater sponges occur in well-oxygenated streams, rivers and ponds. They usually encrust old pieces of submerged twigs and woods or the nets of fish culture cages.

Class Sclerospongiae

Sclerospongiae is a small group of sponges that secrete a massive skeleton. All are restricted to caves, crevices, and other such cryptic habitats on coral reefs or in deep sea. They have a leuconoid canal system and the body is supported by siliceous, calcareous spicules and spongin fiber.

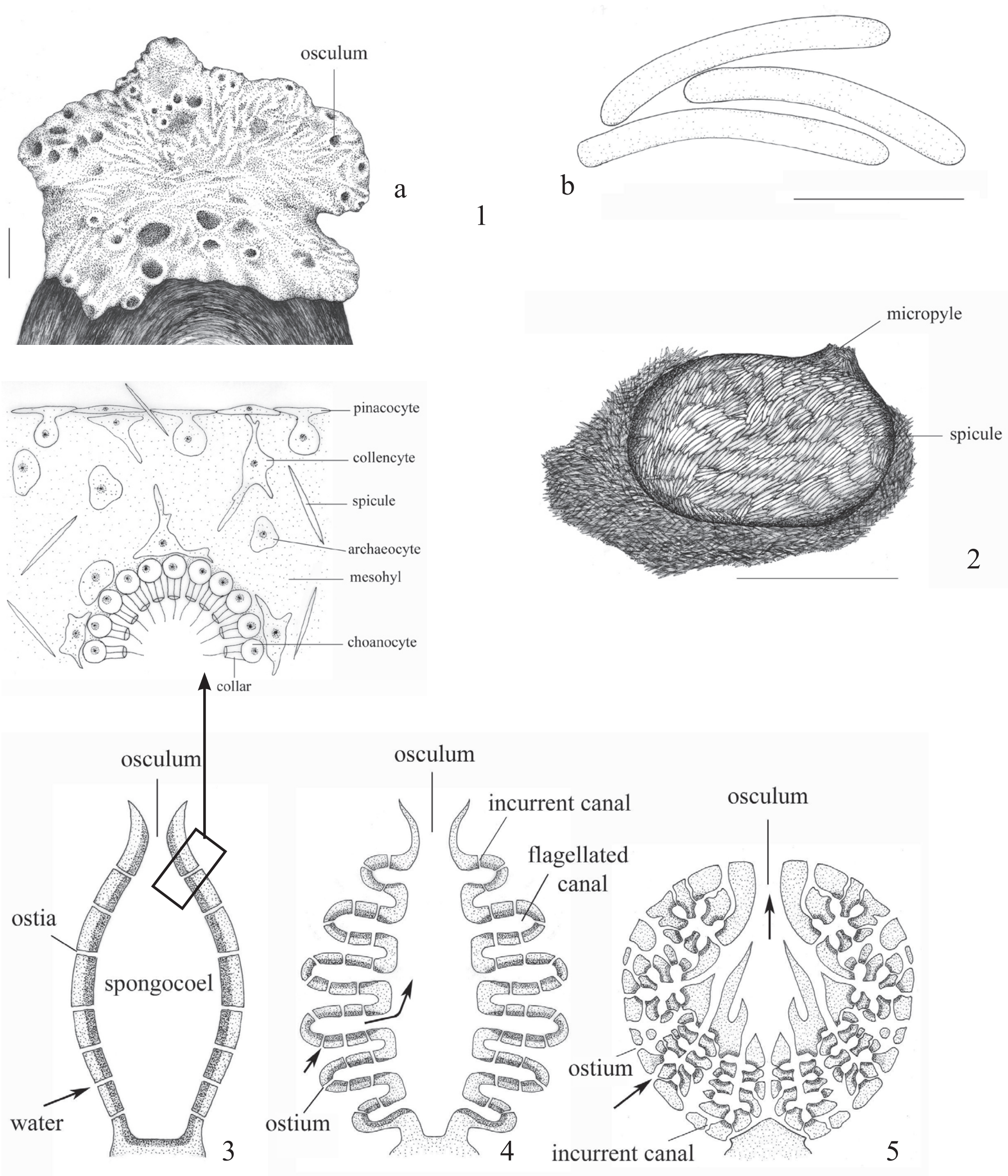


Fig.1–5 1. Typical structure of freshwater sponge (a) and its spicule (b) from the Chi River; 2. Gemmule of freshwater sponge from the Pong River; 3. Asconoid type; 4. Syconoid type; 5. leuconoid type (Fig. 3-5 modified from Barnes, 1963, fig. 4-6 A, B, D and Hickman & Roberts, 1995, fig. 5.6), arrows indicate water flow.
Scale: (1a) 1 cm; (1b, 2) 0.5 mm.

Chapter 3 Phylum Cnidaria

The cnidarians have a tissue level of organisation. They include sea anemones, corals, jellyfishes and the few freshwater hydrozoa. The body has two layers (= **diploblastic**): the epidermis and the gastrodermis, with jelly-like mesoglea between the two layers (Fig. 1b).

General structure and function

Cnidarians have **radial symmetry and** two body forms: sessile **polyps** (tube shaped bodies) which may be solitary or colonial, and free-swimming **medusae** (bell-shaped or umbrella-shaped bodies). Medusae have a much thicker mesoglea layer than polyps making them more buoyant. Both polyps and medusae have tentacles surrounding the mouth, which is the only opening into the digestive system. All cnidarians have cnidoblasts in which the small stinging organelles called **nematocysts** are formed. Nematocysts are a unique characteristic of the phylum, and they are located in both the epidermis and gastrodermis. They are abundant on the tentacles where they may form rings or batteries. Nematocysts function to capture prey and for defence. Tactile stimulation causes the nematocyst to discharge. When it is discharged, its **cnidoblast** is absorbed. Some nematocysts inject poison or penetrate into the prey, but other nematocysts recoil to hold or grasp some part of the prey. Cnidarians prey upon a variety of small invertebrates and vertebrates. The whole prey is drawn into the **gastrovascular cavity**, where gland cells in the gastrodermis discharge enzymes to begin extracellular digestion. In addition, nutritive muscular cells in the gastrodermis phagocytize some food particles for intracellular digestion. Undigested particles are carried into the gastrovascular cavity by amoebocytes and are expelled with other undigested food through mouth to the outside. Hydrozoan medusae have a **velum** below the umbrella.

Cnidarians have a nerve net. There are no excretory and respiratory systems. Ridding of waste products and gas exchange occurs by diffusion.

Cnidarians can be monoecious or dioecious. Asexual reproduction is by budding.

Sexual reproduction involves gamete formation with external fertilization. The zygote develops into the free-swimming planula larva.

Ecological relationships and economic importance in the region

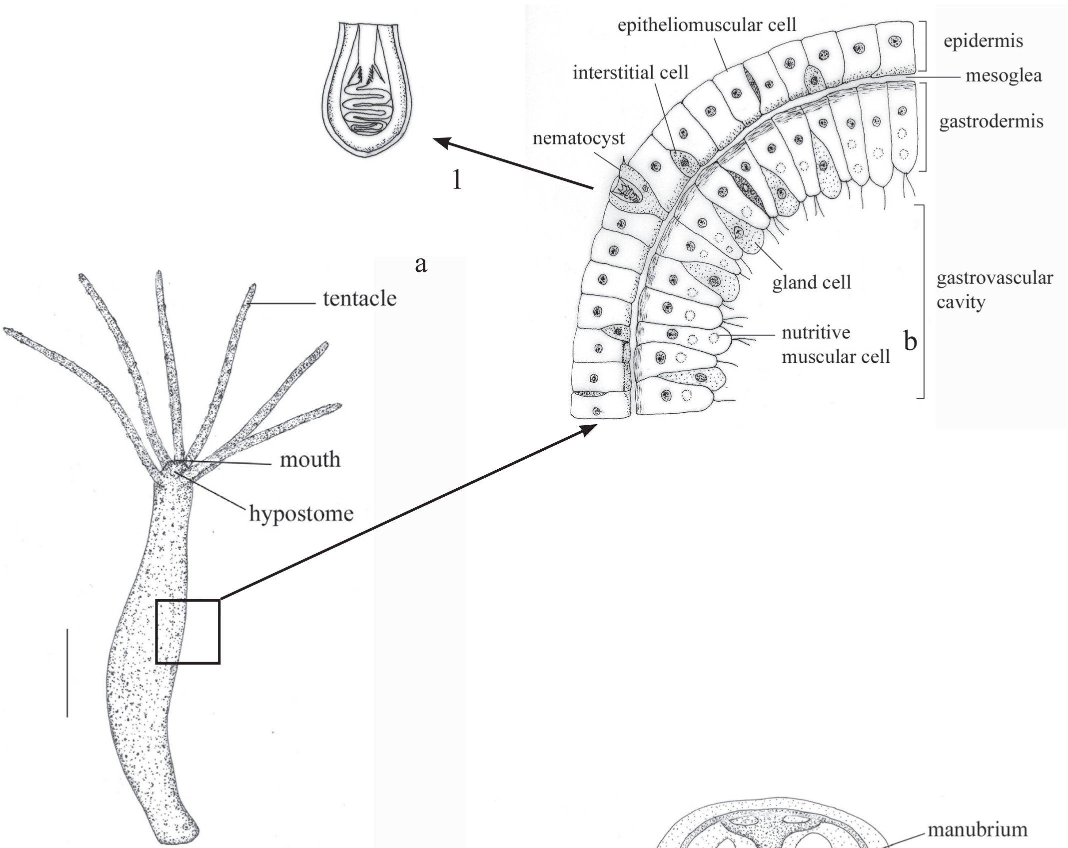
Freshwater hydrozoans are much less diverse than marine forms. They usually feed on water fleas and other small invertebrates. They have no economic value, but they can provide education material for schools and universities.

Classification

Cnidarians are classified into four classes: Hydrozoa, Scyphozoa, Cubozoa and Anthozoa.

Except a few freshwater hydrozoa, all are marine. Hydras of the family Hydridae, order Hydroida (Fig. 1a), are very common freshwater hydrozoans. They have only the polyp form, a slender body and about 4-8 contractile tentacles arranged in a single ring around mouth. Hydras are usually found attached to aquatic vegetation but they may hang from the surface film of water.

Freshwater jellyfish of the family Petasidae, order Trachylina (Fig. 2) are very small medusae that are very rare. They have been found in the Mekong River and its tributaries.



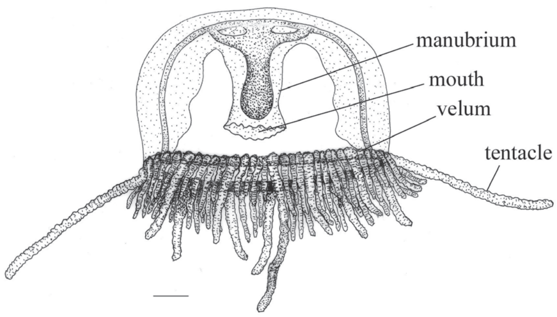


Fig. 1–2 1. Structure (a) and cross section (b) of hydra (1b modified from Hickman & Roberts, 1995, fig. 6.3B); 2. Structure of fresh water jellyfish.
Scale: (1) 1 mm; (2) 2 mm.

Chapter 4 Phylum Platyhelminthes

Platyhelminthes, or flatworms, is a group of organisms, including one class of mostly free-living individuals (Class Turbellaria) and three classes of exclusively parasitic individuals (Class Monogenea, Class Trematoda and Class Cestoda). They are **acoelomate** (have no coelom) and **triploblastic** (three germ layers), and have **bilateral symmetry**.

General structure and function

In the turbellarians, the epidermis forms a protective mucous sheath around the body. In Monogenea, Trematoda and Cestoda the worms have a syncytial integument. Muscles are well-developed and parenchymal cells fill the space between the muscles and visceral organs.

The digestive system is incomplete, and consists of mouth, pharynx and intestine. Undigested food is egested through the pharynx. Turbellarians and trematodes have a highly branched digestive system, which is lacking in cestodes. The cestode host's predigested food directly passes through the integument.

The excretory system of almost all flatworms is composed of two lateral canals with branches bearing **flame cells** (protonephridia). They open to the outside through nephrediopore. Metabolic wastes are largely removed by diffusion through the body wall.

The nervous system consists of a pair of anterior ganglia with two longitudinal nerve cords. The turbellarians and some flukes develop sense organs called **ocelli**, or light-sensitive eyespots. In flatworms, tactile cells and chemoreceptive cells are located all over the body and they are abundant in the auricles (Fig. 1) of planarians.

Most flatworms are monoecious and have cross fertilization. The reproductive system has gonads, ducts and accessory organs. However, many turbellarians can reproduce by fission, and flukes reproduce asexually in their snail hosts.

Ecological relationships and economic importance in the region

The flatworms consist of free-living and parasitic forms. Relatively few turbellarians, such as planarians, live in freshwater habitats. All members of the classes Monogenea, Trematoda and Cestoda are parasitic. Most of the Monogenea are ectoparasites on fishes, but all the trematodes and cestodes are endoparasites in both invertebrates and vertebrates.

Classification

Class Turbellaria

Members of turbellarians usually are free-living forms. The body is covered with a ciliated epidermis containing secretory cells and rhabdites, example: *Dugesia* (planaria) (Fig. 1).

Class Monogenea

The body is covered with a syncytial integument. They are parasitic mostly on the skin or gills of fishes.

Class Trematoda

The body is covered with a syncytial integument. They are leaf-like or cylindrical in shape. They usually have oral and ventral suckers, but no hooks. Foods move from the mouth through the esophagus and into a branched intestine. They are monoecious, with a complex life cycle having invertebrate intermediate hosts and vertebrate final hosts, examples: the liver fluke (*Opisthocis viverini*) and the human blood fluke (*Schistosoma mansoni*).

Class Cestoda

Cestodes, or tapeworms, have a syncytial integument, and are tape-like in shape. The body consists of scolex, neck and proglottids. They are intestinal parasites in vertebrate digestive tracts, examples: pork tapeworm (*Taenia solium*) and fish tapeworm (*Diphyllobothrium latum*).

The most well-known free-living flatworm in freshwater is the planarian (family Planariidae, order Tricladida). Planarians are mainly carnivorous feeding largely on small invertebrates. They use their anterior end to wrap up prey and then they extend the proboscis to suck up the food. They usually glide around on rocks and debris in both flowing and standing water habitats.

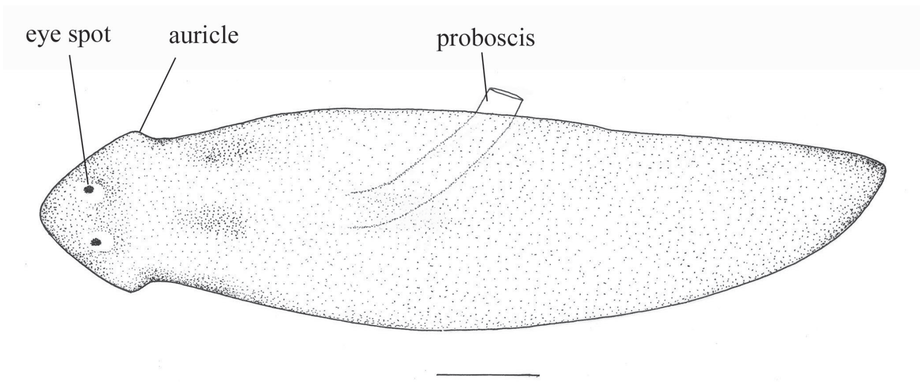


Fig. 1 Structure of planarian.
Scale = 1 mm.

Chapter 5 Phylum Rotifera

Rotifera is a small group of **pseudocoelomate** animals that live in freshwater habitats ranging from temporary ponds to rivers. The body is divided into three regions: a head, a trunk and a foot. The head region bears the ciliated crown or **corona** (Fig. 1). Rotifers are filter feeders that consume plankton. The coronal cilia create currents of water that direct water and food toward the mouth. Foods are grasped and chewed by a muscular pharynx, called the **mastax**, which is a unique rotifer characteristic. Rotifers use toes, which secrete a sticky substance from pedal glands for attachment. Rotifers are dioecious, but some species reproduce only by **parthenogenesis**. Rotifers have two types of eggs, **amictic eggs** and **mictic eggs**. Amictic eggs are diploid eggs that develop directly into females. Mictic eggs are haploid eggs. If unfertilized mictic eggs develop quickly and parthenogenetically into males; if fertilized, they secrete a thick shell and become a dormant egg for several months before developing into a female the next year.

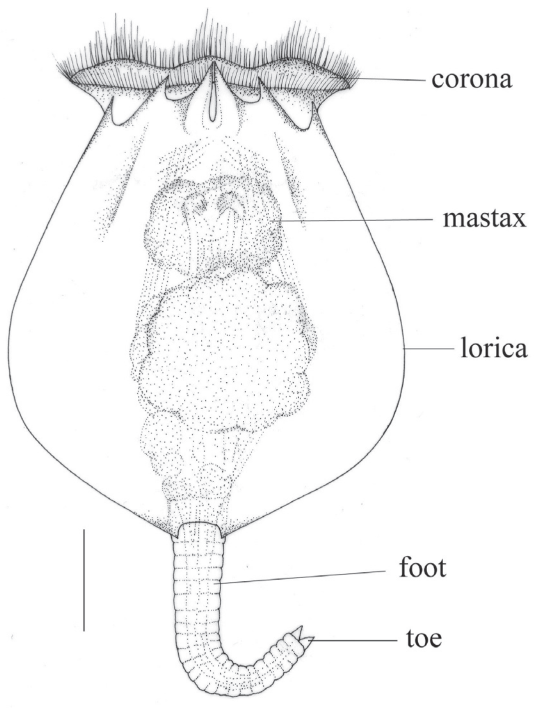


Fig. 1 Structure of *Brachionus rubens*.
Scale = 50 µm.

Chapter 6 Phylum Nematoda

Nematodes, or roundworms, (Fig. 1) are translucent, slender, unsegmented, cylindrical **pseudocoelomate** worms. The body typically tapers at the posterior end. Nematodes are dioecious. Most nematodes are parasitic in plants and animals. Free-living nematodes feed on organic matter, algae and diatoms. Parasitic nematodes cause both public health and economic problems.

Fig. 1 Structure of freshwater nematode.
Scale = 0.5 mm.

Chapter 7 Phylum Nematomorpha

Horsehair worms (Fig. 1) are unsegmented, cylindrical, very long and slender worms with blunt anteriors. The body is covered by a thick layer of cuticle. Juveniles are parasitic in terrestrial insects and adults are free-living in water. Adults have a vestigial digestive tract and do not feed. They usually are found wriggling slowly among aquatic plants. Females lay eggs attached to aquatic plants.

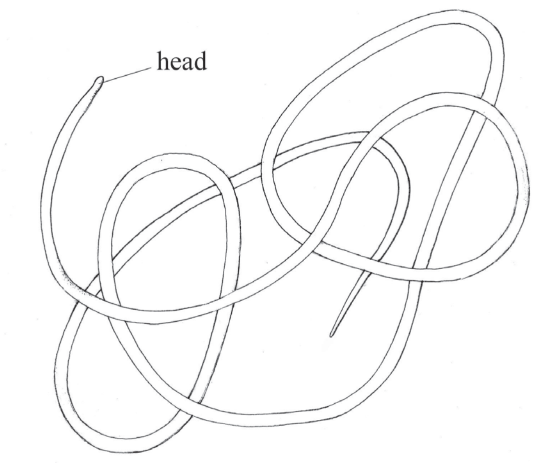


Fig. 1 Structure of horsehair worm.

Chapter 8 Phylum Bryozoa (= Ectoprocta = Polyzoa)

Bryozoa, or moss-animals, is a small group of tiny organisms that live interconnected in a colony. The colony consists of fine branching tubes and is plant-like in form. Most bryozoans are sessile and immobile. They grow on all types of hard substrates or on sediments in standing water, streams and rivers. There are about 5,000 living species, and most are marine. The freshwater forms include about 50 species (Dudgeon, 1999) and most are members of the class Phylactolaemata.

General structure and function

An individual bryozoan is called a zooid. One zooid consists of the **polypide** (or organ system) and the **cystid** (or body wall or house). A polypide is composed of the **lophophore**, stomach, gonad, nerve ganglia and musculature. The mouth opens into a U-shaped gut, the anus is located outside the lophophore. The epidermis secretes the **zooecium**, or non-living part of the body wall. The epidermis and zooecium produce the cystid. Polypides have three main structures: lophophore, retractor muscles and **funiculus** (Fig. 1b). The lophophore is a crown of ciliated tentacles arranged around a central mouth, and it functions by capturing suspended food particles. It can be withdrawn into the cystid for protection and protruded through the opening of the cystid (the orifice) for gas exchange and feeding. The funiculus is a thin strand of tissue where **statoblasts** are formed and spermatogenesis takes place. Colonies have two types of zooecia: a mass of cuticular branching tubes or a mass of gelatinous zooids. Tubular zooids are fixed and form an encrusting colony spread out over rocks and other substrates. The gelatinous zooecia usually have zooids embedded in the jelly and the colony is not fixed to the substrate.

Bryozoans are filter feeders. Food particles mostly are small microorganisms, including protozoans, diatoms and unicellular algae. Food particles are trapped by lophophore, and then swallowed through a pharynx to the stomach. Digestion occurs within the stomach and it involves both extracellular and intracellular phases. They have no excretory organs. Waste products are collected by coelomic amoebocytes, consolidated, infused with mucus in the intestine, and then ejected as a fecal pellet through the anus.

Respiratory and circulatory systems are absent. Gas exchange occurs through the body surface. There is a ganglionic mass and a nerve ring around the pharynx, but no sensory organs.

Phylactolaemate bryozoans can reproduce both sexually and asexually. Asexual reproduction is by budding, fragmentation or statoblast formation. Statoblasts are an encapsulated resistance bud that may be seen within the zooecium. In general, mature statoblasts consist of two regions: the central and peripheral regions. The central region is a thick capsule containing a mass of undifferentiated germinative cells. The peripheral region (called the annulus or float) is a relatively thin area containing air cells. Sometimes the peripherial region bears spiny, barbed, or hooked processes. There are three major types of statoblasts:

annulate floatoblasts (Fig. 1c) which are free or can floating after the zooecium disintegrates; sessile sessoblasts (Fig. 1d) which are cemented or fixed to the zooecium wall; and the piptoblasts (Fig. 2b), which sink to the bottom when the zooecium disintegrates. The statoblast remains dormant for some time and germinates and forms a new zooid when conditions are favorable. Statoblasts are important in species identification. In sexual reproduction, sperms develop in conspicuous masses on the funiculus of certain zooids. They are released through the lophophore. Eggs develop as a cluster on the peritoneum ventrally within the zooid. They usually have cross-fertilization in the coelom. Zygotes develop into ciliated larvae that are free-swimming before settling onto the substrate to become a sessile adult.

Bryozoans can encrust pipes or grow into pipes and clog water intakes. Many marine bryozoans produce a remarkable variety of chemical compounds, and some are being tested for use as medicines.

Classification

There are 3 Classes: Phylactolaemata, Gymnolaemata and Stenolaemata. Stenolaemata and most Gymnolaemata are marine, while Phylactolaemata is exclusively freshwater. *Plumatella* is a common genus in tropical countries.

The following key to families of freshwater Bryozoa is modified from Pennak (1989) and Wood (2001).

Key to Families of Freshwater Phylactolaemata Bryozoan

1 Lophophore circular or elliptical; zooecium a tubular colony (Fig. 2a), no floatoblasts; piptoblasts are free and lack an annulus (Fig. 2b)........ Fredericellidae

1′ Lophophore U-shaped (Fig. 1b); zooecium branching and tubular, or gelatinous; floatoblasts and/or sessoblasts 2

2 Zooecium of branching tubes (Fig. 1b); floatoblasts present (Fig. 1c); sessoblasts usually present (Fig. 1d) .... Plumatellidae

2′ Zooecium a gelatinous mass; free statoblasts.....................................Lophopodidae

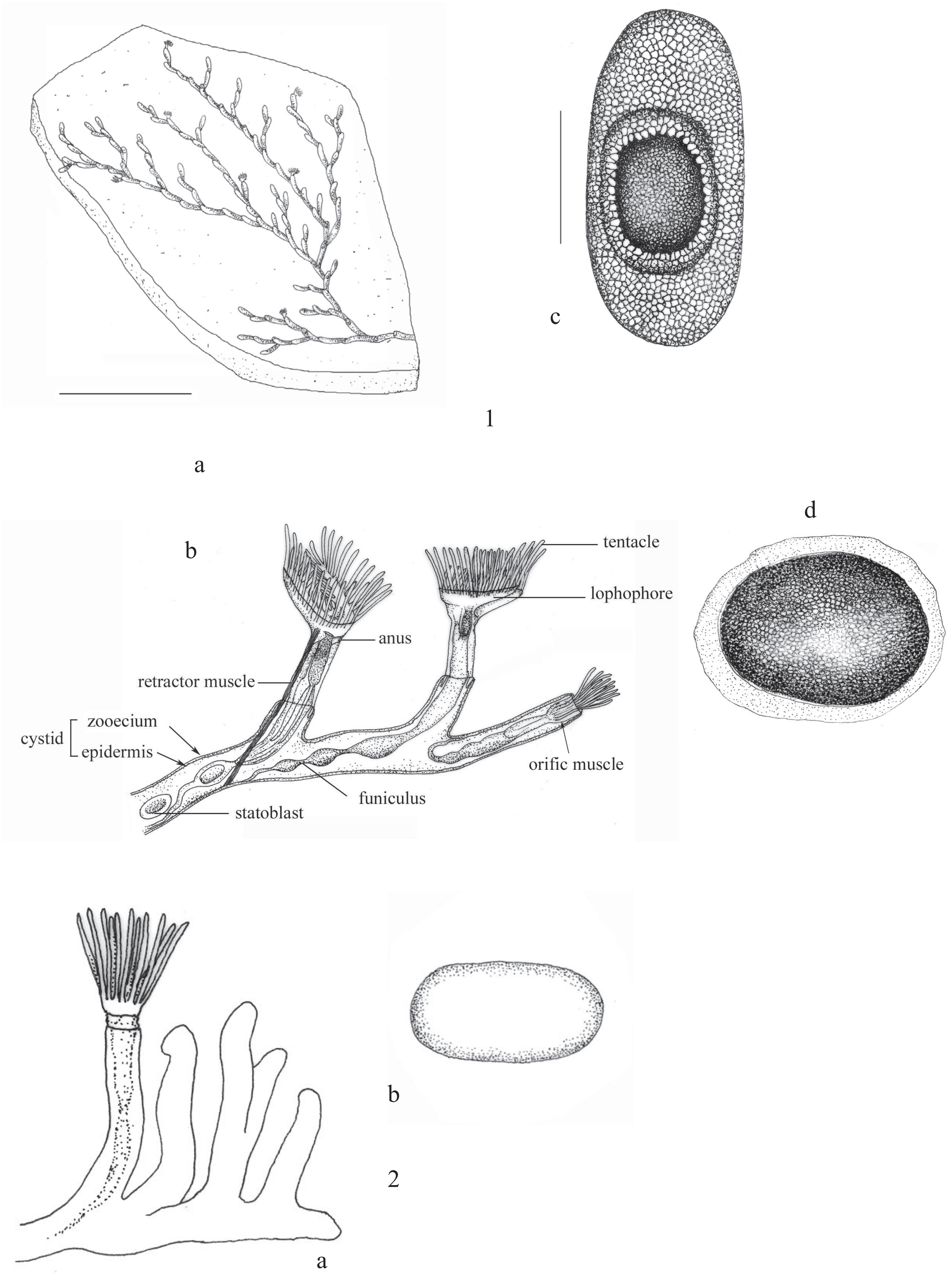


Fig. 1-2 1. Colony (a), enlarged part of colony (b), floatoblast (c) and sessoblast (d) of *Plumatella* sp. (1d redrawn from Pennak, 1989, fig. 1A); 2. Part of colony (a) and piptoblast (b) of Fredericellidae (modified from Pennak, 1989, fig. 10, 18B). Scale: (1a) 2 mm; (1c) 50 µm.

Chapter 9 Phylum Annelida

Annelids, or segmented worms, are different from round worms and horse-hair worms. They have a series of repeating segments. The serial repetition of segments and organ systems is called **metameric segmentation**, and is one of the main characters of this phylum. Members include polychaetes, oligochaetes and leeches.

General structure and function

Annelid worms have a soft body wall which contains both circular and longitudinal muscles. These muscular layers are covered with an epidermis and a thin layer of nonchitinous cuticle (Fig. 1). Annelids have a **true coelom**, and it is divided by septae. The coelom of polychaetes and oligochaetes is filled with fluid and functions as a hydrostatic skeleton. Alternating waves of contraction by the longitudinal and circular muscles result in a peristaltic contraction of the body wall. This movement aids polychaetes and oligochaetes in locomotion and burrowing. In contrast, leeches swim by undulating their bodies.

Annelids have a closed circulatory system, and gas exchange occurs through the moist skin, gills or fleshy appendages called parapodia. The digestive system is complete and not segmentally arranged. The mouth opens on the peristomium and an anus opens at the posterior end. A pair of nephridia in almost all segments functions in excretion; however, some wastes are excreted directly across the epidermis.

Most polychaetes are dioecious, and have sexual reproduction and trochophore larvae. Oligochaetes and leeches are hermaphroditic and have cross-fertilization. Larvae develop in external cocoons.

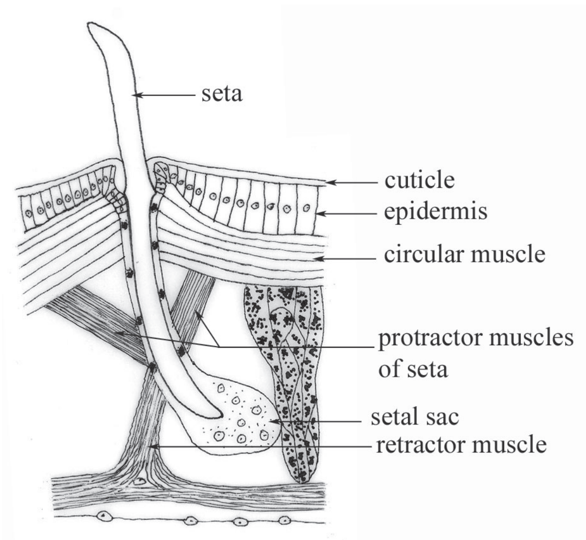


Fig. 1 Transverse section of body wall of the earthworm (redrawn from Barnes, 1963, fig. 11–38B)

Classification

Annelids are classified into 3 classes : Polychaeta, Oligochaeta and Hirudinea. A few polychaetes, or bristleworms, are freshwater but almost all oligochaetes (earthworms and relatives) and hirudines (leeches) are freshwater. Freshwater oligochaetes are small, usually translucent and thread-like. The family Tubificidae is common, especially in muddy sediments where there are high levels of organic contamination. It is an indicator of poor water quality. Leeches have suckers at the anterior and posterior ends of the body. They often are found clinging under stones or plant leaves or burrowing in soft sediments. Leeches feed on small invertebrates or suck the blood of vertebrates. The key to the classes of freshwater annelids is available in Chapter 1. A key to the common families of freshwater leeches is as follows.

Key to Families of Freshwater Leeches

1 Anterior sucker with a very distinct complete rim (Fig. 2) ; four eyes, parasites of fishes .... Piscicolidae (fish-leeches)

1' Anterior sucker with part of the rim not distinct from body (Fig. 3) two to ten eyes 2

2(1') Anterior sucker indistinct; mouth large; body flattened cylindrical shaped (Fig. 5a); 8-10 eyes.. 3

2' Anterior sucker fairly distinct; mouth a small pore in the central of the sucker region; body rose apple-shaped in outline; 2-8 eyes (Fig. 3) .... Glossiphoniidae

3(2) Eight eyes; small or medium size leeches without jaws (Fig. 4)........Erpobdellidae

3' Ten eyes; large leeches with strong jaws (Fig. 5)...................................Hirudinidae

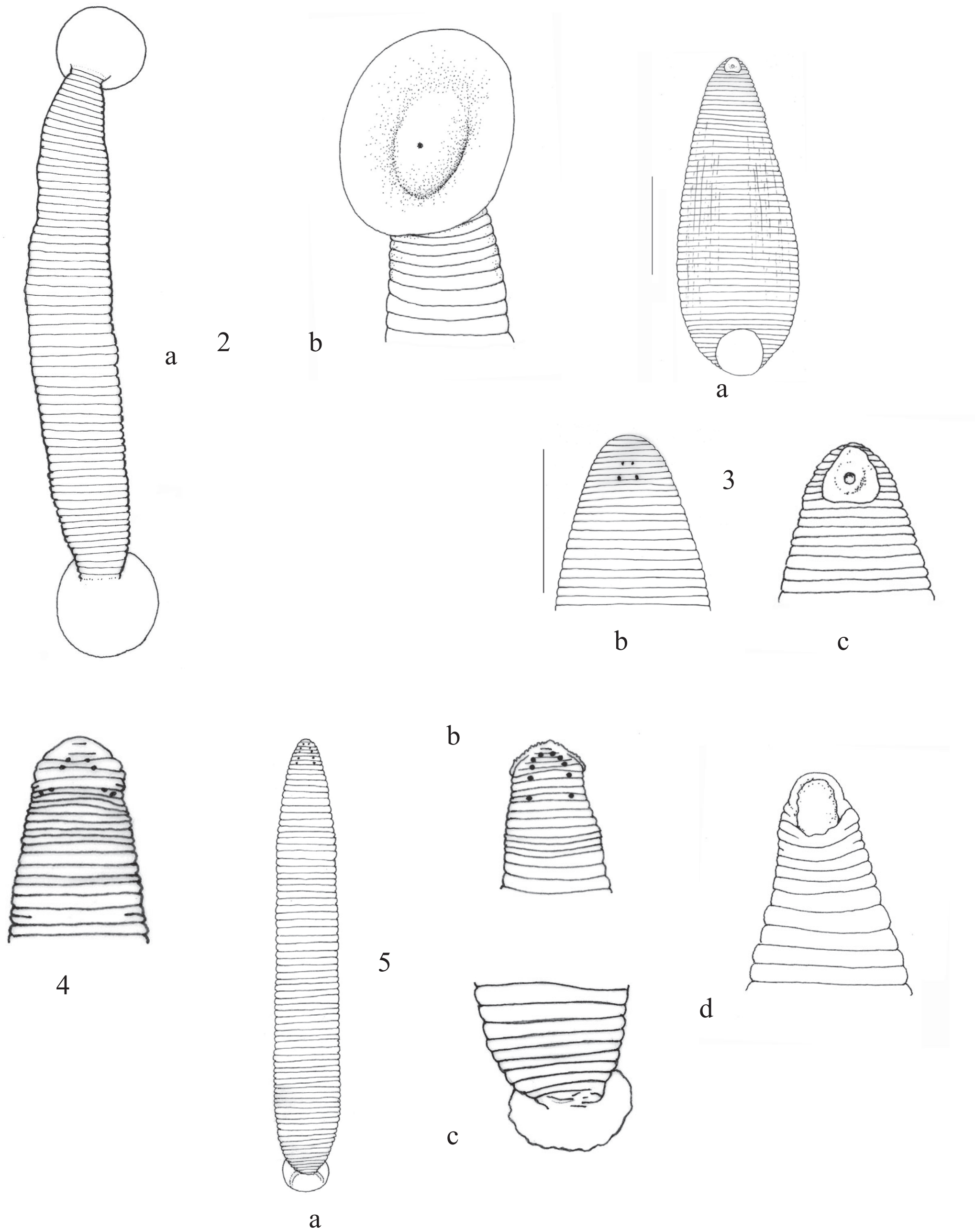


Fig. 2-5 2. Dorsal view (a) and anterior sucker (b) of Piscicolidae (modified from Pennak, 1989, fig. 36C); 3. Ventral view (a), dorsal view (b) and ventral view of anterior (c) of Glossiphoniidae; 4. Dorsal view of anterior of Erpobdellidae (redrawn from Pennak, 1989, fig. 33C); 5. Dorsal view (a), dorsal view of anterior (b), dorsal view of posterior (c) and anteroventral view (d) of Hirudinidae (redrawn from Pennak, 1989, fig. 27, 33B, 33L). Scale = 1 mm.

Chapter 10 Freshwater Mollusca

The phylum Mollusca is one of the largest animal phyla next to the phylum Arthropoda. The name mollusca indicates their soft body characteristic. There are six classes: Polyplacophora (chitons), Monoplacophora, Gastropoda (snails and their relatives), Pelecypoda (bivalves) and Cephalopoda (squids, octopus and nautiluses). Some members of Gastropoda and Pelecypoda occur in freshwater where they are diverse and important components in freshwater habitats.

General structure and function

The body consists of a **head-foot** portion and a **visceral mass** portion (Fig. 1). The head-foot is the more active area containing the feeding, sensory and locomotion organs. Within the mouth of many molluscs is the radula. The radula is a ribbon-like series of rows of tiny teeth that point backward. Each row of teeth has teeth of three types; rachis (central), lateral and marginal teeth (Fig. 2). The number of each tooth type varies among species and aids species level identification in some gastropods. When the radula is protruded, the snail can scrape, pierce, tear or cut food materials.

The visceral mass is the portion containing digestive, circulatory, respiratory and reproductive organs. The **mantle** is a sheet of tissue produced from the dorsal body wall. The space between the mantle and body wall is called the mantle cavity. It houses the gills (ctenidia) or lungs, and in most molluscs the mantle secretes the **shell**. The shell protects the soft visceral mass portion. Shell secretion is a continuous process throughout the life of shelled molluscs. The shell consists of three layers: the outer, thin horny layer, or **periostracum**; the middle, thick **prismatic layer** laid down on a protein matrix; and the inner, thin calcium carbonate sheets laid down over a thin protein matrix, or the **nacreous layer** (Fig. 3). The mantle surface continuously secretes the nacreous layer so that it becomes thicker throughout the animal′s life. In some bivalves if a grain of sand, parasite or other foreign particle becomes trapped between the mantle and the inner surface of shell, the formation of pearl may occur over a period of years. In freshwater molluscs a thick periostracum protects against the acids produced in water by decaying leaf litter. Molluscs obtain calcium for making their shells from the water or food.

Gas exchange occurs through the body surface, mantle and particularly by gills or lungs, which are derivative of the mantle. Almost all molluscs (except most cephalopods) have an open circulatory system. It consists of one or more hearts (usually three), blood vessels, and sinuses which comprise a hemocoel. The nervous system consists of several pairs of ganglia with connecting nerve cords. Freshwater mollusks have internal fertilization.

Ecological relationships and economic importance in the region

Freshwater molluscs are diverse and include herbivorous grazers, predators and ciliary filter-feeders. Unlike gastropods, filter-feeding bivalves inhabit only aquatic habitats. Many river bivalves and freshwater snails (mostly *Filopaludina* and *Pila*) are used as food and are sold in the market. Some freshwater bivalves can produce pearls. The giant freshwater clam, *Chamberlainia*, was harvested for its nacreous shell to supply the furniture industry in Thailand. Small pieces of nacreous shell were embedded into the wood for decorating. The introduced apple snail, *Pomacea*, is widespread and damages rice fields and vegetable crops in many Indochina countries. Many freshwater snails are intermediate hosts of parasites in human and domestic animals.

Class Gastropoda

Most gastropods bear a protective, one piece, coiled or uncoiled shell. Some snails have a horny plate, the operculum, that covers the shell aperture. Opercula have many shapes ranging from pausispiral to concentric (Fig. 4). During early development of snails the mantle cavity of the veliger larvae moves to the front of the body, thus twisting the visceral mass through 90-180 degrees (Fig. 5a-b). This phenomenon is called torsion. After torsion, the anus and mantle cavity become anterior and open above the mouth and head (Fig. 5b). The left gills, kidney and heart auricle are now on the right side, whereas the original right gill, kidney and heart auricle are now on the left side. The organs on the right side not well-developed. The nerve cords and digestive system are also obviously twisted. Water passes into the left side of the mantle cavity and out the right side, carrying waste products from mantle cavity. Pulmonate snails lose their gills and the mantle cavity increases in volume and becomes a lung. Flow of air or water into and out of the lung occurs through a single small opening called **pneumostome**.

In general, the animal is attached to the inside of the shell by a columellar muscle, which extends from within the animal′s foot to the central axis of the shell. The center of the shell is called the **columella** (Fig. 6). The columellar muscle allows protraction from the shell, retraction into the shell, twisting, etc. The retractor muscles on the right side of body develop before those of the left, so that the mantle cavity and associated organs were pulled along the right side of animal toward the front.

There are both dioecious and monoecious gastropods. The Ancylidae, Lymnaeidae, Planorbidae and Physidae are hermaphroditic. Self-fertilization is avoided by an exchange of spermatophores during copulation. Internal fertilization occurs in terrestrial and freshwater snails. The ovary and testis are located at the tip of the spire. The ducts lie in the foot and body whorl. The male genital pore is usually located near the base of the right tentacle. It is commonly at the end of a muscular, protrusible, intromittent organ (the copulatory organ or **penis**) which is protruded only during copulation. In the Viviparidae, the right tentacle is modified as a intromittent organ (Fig. 1). In the Hydrobiidae, the copulatory organ, usually called a **verge** (Fig. 9), remains protruded and cannot be retracted. The female genital pore is unspecialized and usually lies at the base of the neck near the pulmonary opening, or at the mantle cavity.

Some freshwater snails lay eggs in a cluster attached to leaves of aquatic plants. Eggs are covered with jelly. The juvenile stage takes place in the egg. Most pulmonate snails develop into miniature snails within the ovary.

Many freshwater and terrestrial snails are intermediate hosts for serious parasites of both humans and domestic animals in Indochina. For example: *Bithynia* is an intermediate host of human liver fluke, *Opisthorchis*; *Neotricula aperta* is an intermediate host of human blood fluke, *Schistosoma mansoni*; and, *Lymnaea auricularia* is an intermediate host of cattle liver fluke, *Fasciola hepatica*. Some members of Pilidae and Viviparidae are intermediate hosts of rat lung worm, *Angiostrongylus cantonensis*. The real intermediate host of this parasite is a rat but humans receive parasitic worms by eating raw or undercooked snails. The parasite enters the human digestive tract, then migrates through the body, often penetrating the brain or eyes. This parasite may cause the patient to die or be blind.

Shells of Gastropods

The important features of a typical gastropod shell are shown in Fig. 6. The opening of the shell is called the **aperture**, and the main portion of the shell above the aperture is the **spire**. The first large coil, or whorl, of the shell is the **body whorl**. The small round knob of from 1¼ to 1½ whorl without distinct sculpturing, and at the apex of shell is the nucleus whorl or protoconch. The whorls are coiled around a central axis or columella. An inner lip at the columella margin of the aperture is usually present and reflected over the columella region. The inner surface of shell immediately adjacent to the inner lip is called the parietal wall. The peristome or outer lip lies along aperture. The umbilicus may be a small chink or a narrow slit between the reflected inner lip and the body whorl. In many species the umbilicus is sealed.

Gastropods have a variety of shell shapes, sizes, and surface markings. Shell shape varies from elongate to cap (Fig. 7) and the opercula vary from paucispiral to concentric (Fig. 4). In most gastropods, the surface of the shell is smooth, but some have longitudinal growth (axial) lines and spiral sculptures. In a few species the shell bears prominent ornamentation and color bands (Fig. 8).

The shell of most gastropods coils clockwise, so that the shell is right-handed or dextral (Fig. 6a). Relatively few snails coil counterclockwise, so that the shells are left-handed or sinistral (Fig. 6b).

Brandt (1974) collected specimens of non-marine aquatic molluscs from Thailand, Mynmar, Lao PDR and Cambodia. His text book *The non-marine aquatic Mollusca of Thailand* provided keys and some ecological notes. Among gastropods, the taxa richness of freshwater prosobranch snails is greater than that of pulmonates (Brandt, 1974). Prosobranchs are often found in lotic waters while pulmonates usually occur in lentic waters.

The following keys for Gastropoda are modified from Brandt (1974), Chitramvong (1992) and Upatham *et al.* (1983).

Class Pelecypoda (= Bivalvia)

Pelecypoda, or bivalve molluscs, are all aquatic, and occur in nearly all freshwater habitats. They are divided into three subclasses based on gill structure—the Protobranchia, the Lamellibranchia and the Septibranchia. Bivalves are laterally compressed and their two valves (shell) are held together dorsally by a hinge ligament that springs the valves apart ventrally when the adductor muscles relax. Projecting above the hinge ligament on each valve is the umbo, which is the oldest part of the shell. The foot is axe-shaped and located at the anteroventral margin. The inhalant and exhalent siphons are at the posterior margin. The siphons are modified from posterior edges of the mantle fold. Bivalves lack heads, tentacles, eyes and radulas (Fig. 10). The visceral mass is suspended from the dorsal midline, and the muscular foot is attached to the visceral mass. The gills hang down on each side and each is covered by a mantle fold. Bivalves are ciliated filter-feeders. Cilia on the gills and inner surface of mantle direct the water flow over the gills. Food particles suspended in the water are trapped by mucus secreted by glandular cells on the gills. Then the food is passed to the mouth. Food is digested in the stomach and wastes are expelled from the anus into the excurrent siphon.

Bivalves are dioecious, and unlike marine bivalves, internal fertilization occurs in freshwater clams. The gill tubes serve as the temporary brood chambers, where the zygotes develop into tiny bivalve **glochidia larvae**. The glochidia larvae (Fig. 11a) are discharged with the excurrent flow, and come to contact with a passing fish. They attach to the fish′s gills and fins (Fig. 11b) for many days before dropping off and sinking to the bottom to become the sedentary adults.

Shell shape in bivalves varies from elongate to trapezoidal (Fig. 12). The important features of the inner surface of a typical shell are shown in Fig. 13. Near the dorsal margin there are interlocking hinge teeth which aid in keeping the two valves in close position. The spring-like ligament keeps the shell slightly open. The **cardinal** (Fig. 14) and **pseudocardinal** (Fig. 13) teeth also interlock. The valves are closed by the anterior and posterior adductor muscles that work in opposition to the **hinge ligament**. When the adductor muscles are contracted the valves close. When the **adductor muscles** are relaxed, the valves open. Most freshwater bivalves burrow into sand or a crevice in a rock at the bottom of stream or river. The valves are slightly opened allowing water to flow into the **incurrent siphon** (Fig. 10) for feeding and respiration. Freshwater mussels may form beds on rocks or snags in the shallow water near the shore (Fig. 15).

Taxa richness and abundance of bivalves is greater in rivers. In Indochina, *Corbicula* is a representative genus in streams while the Amblemidae is diverse and abundant in rivers.

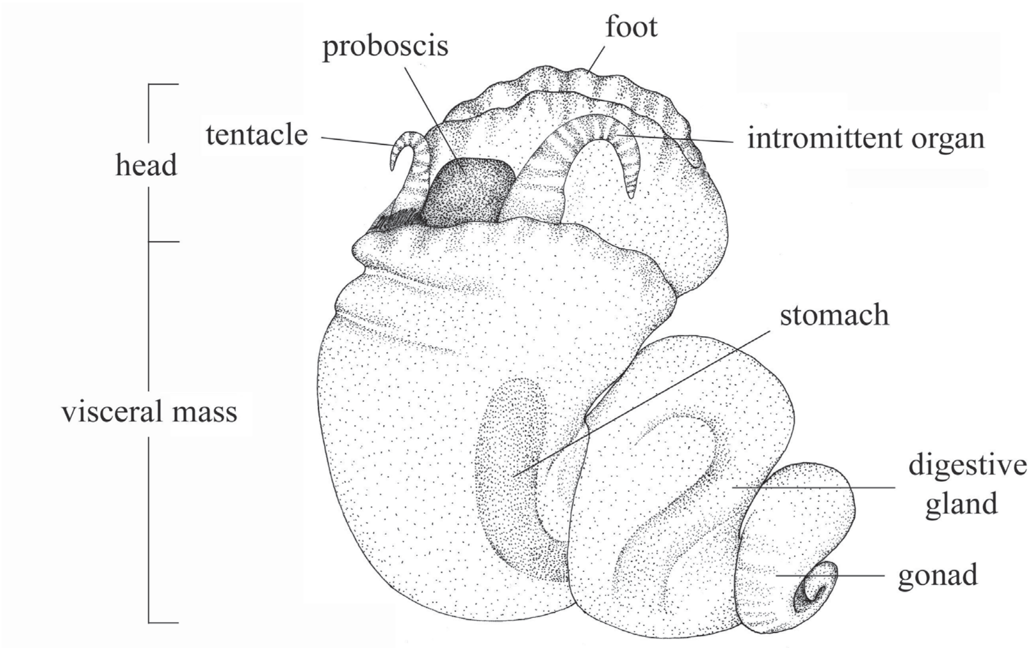


Fig. 1 View of head-foot and visceral mass of *Filopaludina* (*Siamopaludina*) sp. (Viviparidae).

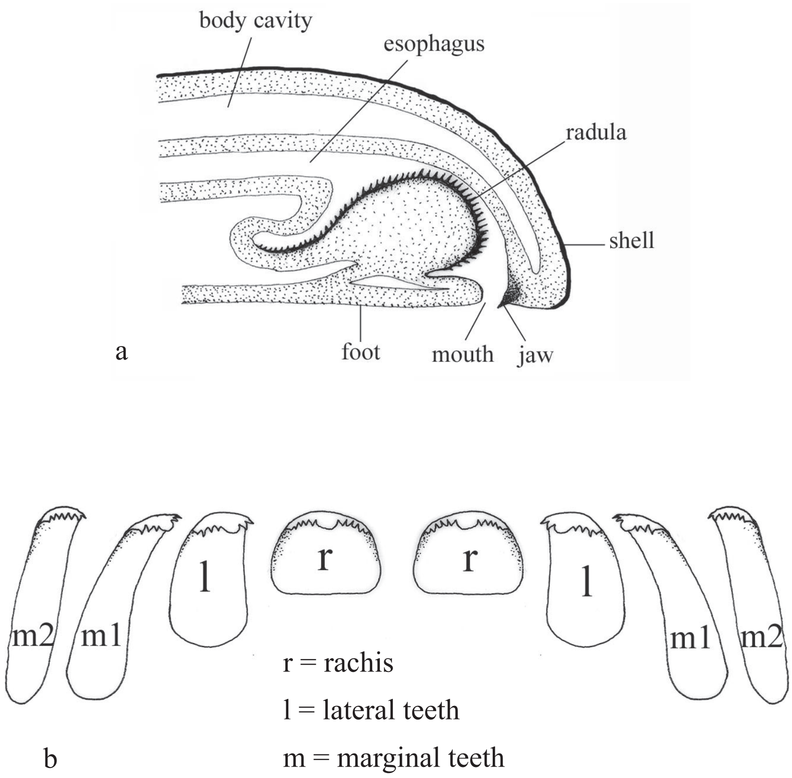


Fig. 2 a) Diagrammatic longitudinal section through the anterior end of a snail (redrawn from Pennak, 1989, fig. 5); b) structure of radula (modified from Pennak, 1989, fig. 7C).

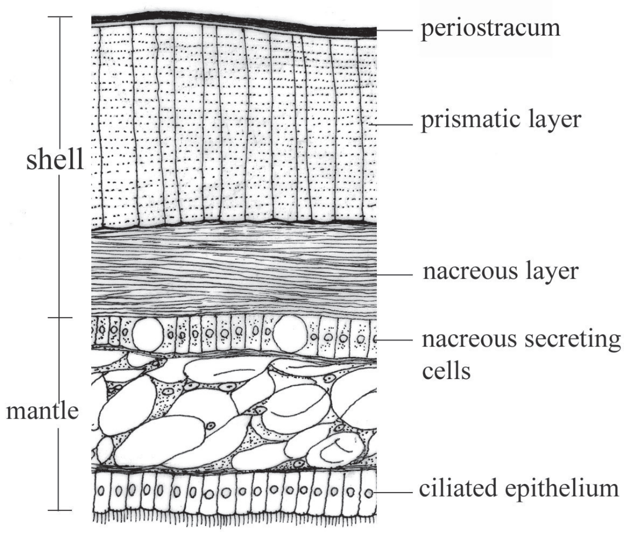


Fig. 3 Enlarged cross section of shell and mantle of freshwater clam (modified from Storer & Usinger, 1957).

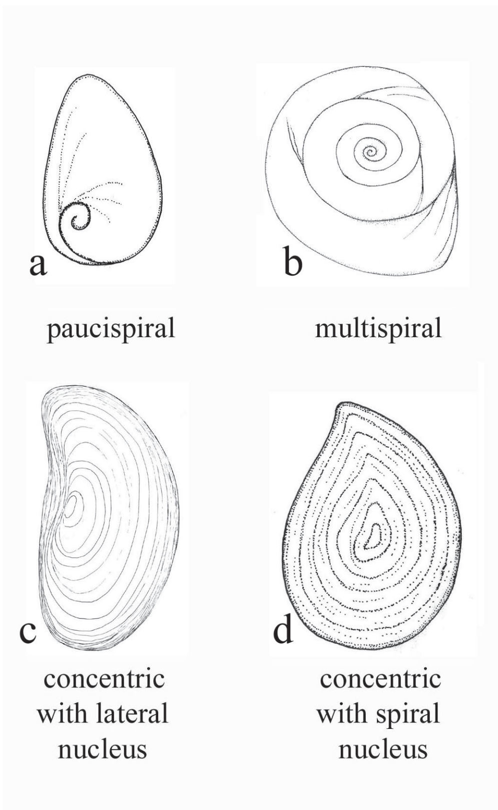


Fig. 4 Types of gastropod opercula.

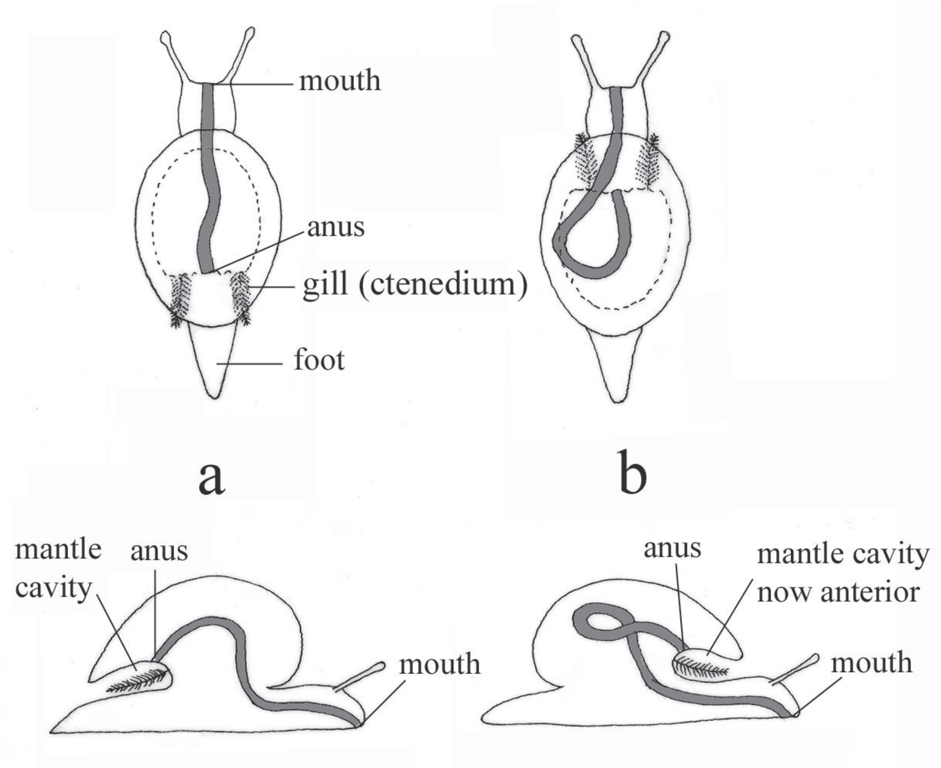
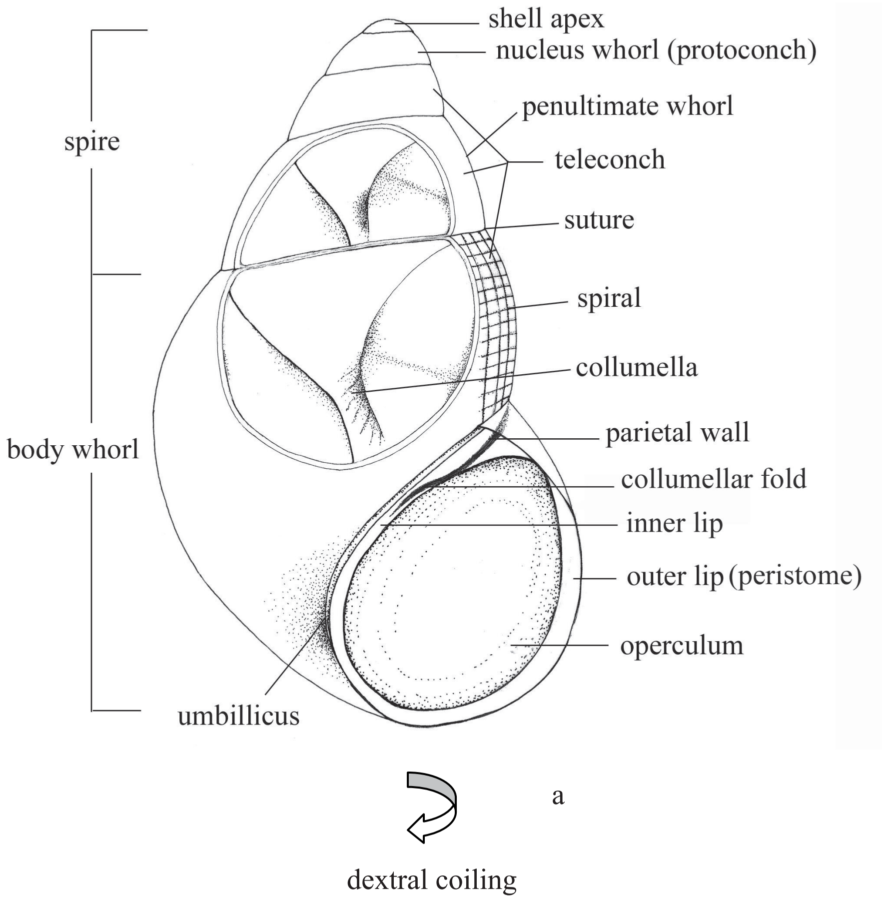


Fig. 5 Torsion in gastropods, (a) ancestral condition before torsion; (b) early gastropod, torsion complete (redrawn from Hickman & Roberts, 1995, Fig. 9.11).



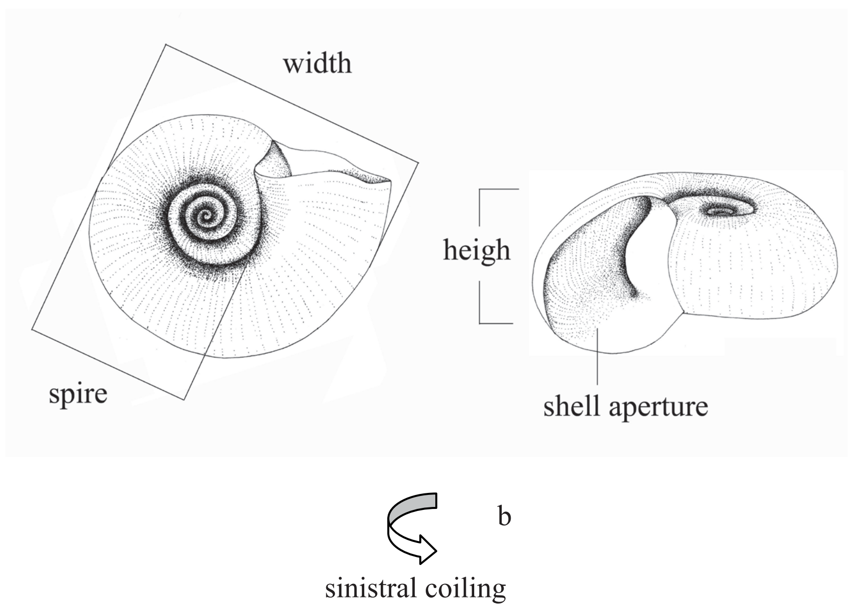


Fig. 6 a) Major external features and longitudinal section of a typical gastropod shell;
b) Discoidal shell and sinistral coiling of gastropod.

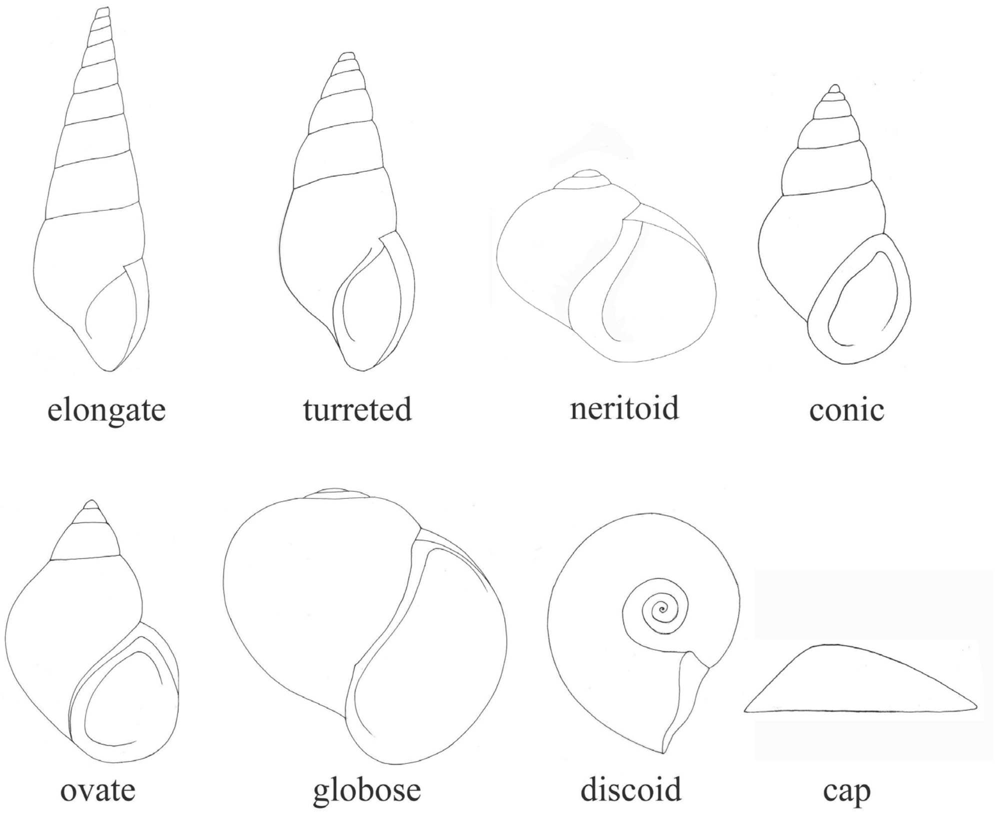


Fig. 7 Variation in shell shape in gastropods.

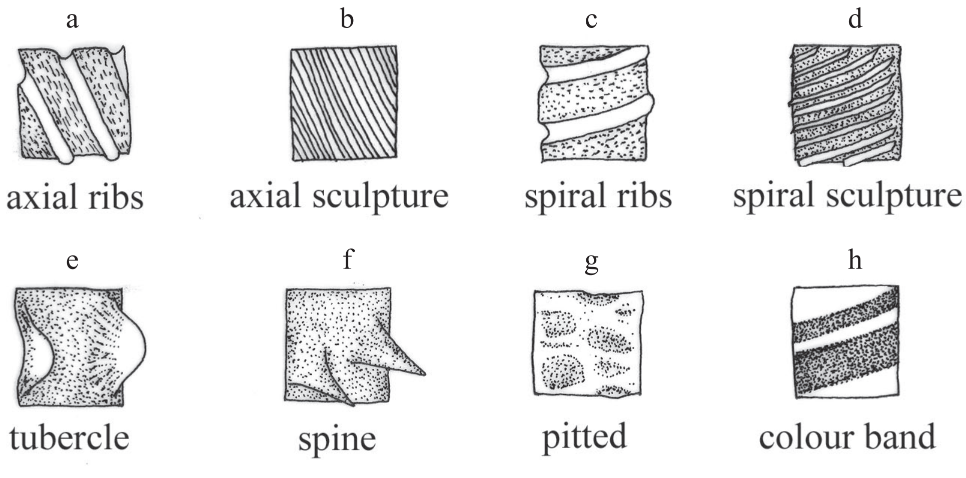


Fig. 8 Shell sculpture in gastropods.

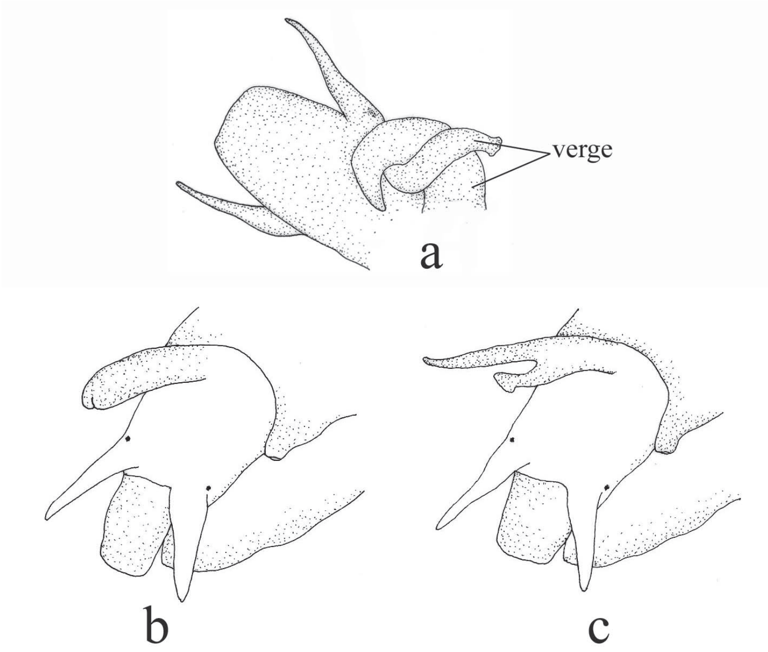


Fig. 9 Verge of Bithynidae (a); simple verge (b); and branched verge (c) of Hydrobiidae (modified from Pennak, 1989, fig. 11,13A-B).

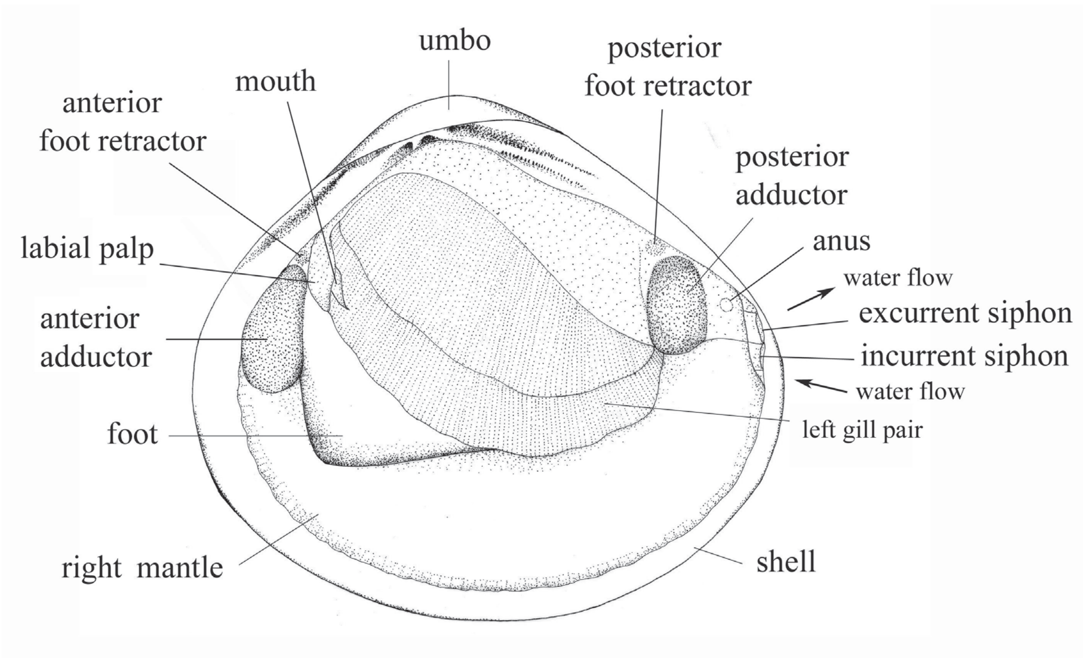


Fig. 10 Lateral view of external morphology of *Corbicula* sp. (Corbiculidae), left shell removed.

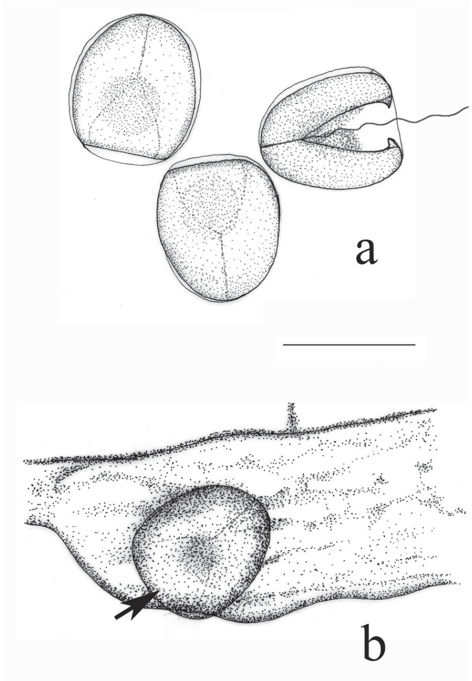


Fig. 11 Glochidia larvae of *Hyriopsis* (*Limnoscapha*) *myersiana* (a) and enclosure of a glochidium on the dorsal fin of *Helostoma temmicki* (b) (modified from Panha, 1991, fig. 1).
Scale = 25 µm.

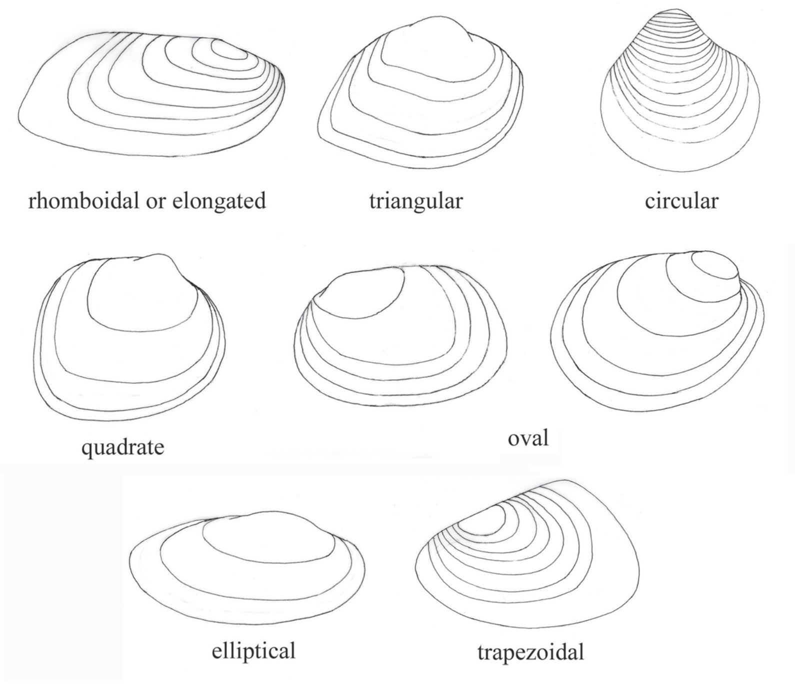


Fig. 12 Shell shapes in pelecypods.

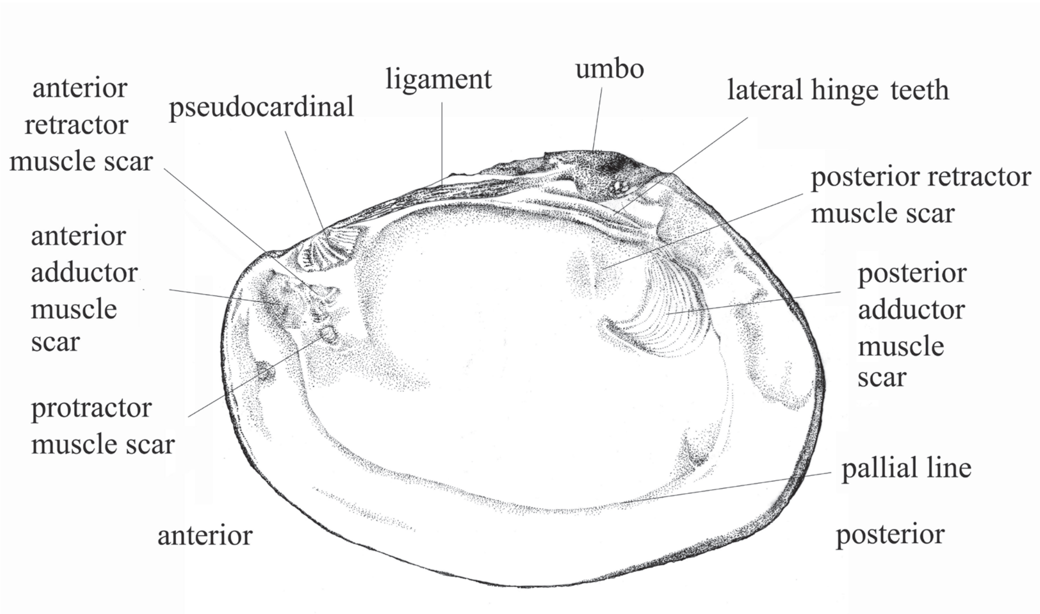


Fig. 13 *Chamberlainia hainesiana*, showing general features inside the right shell.

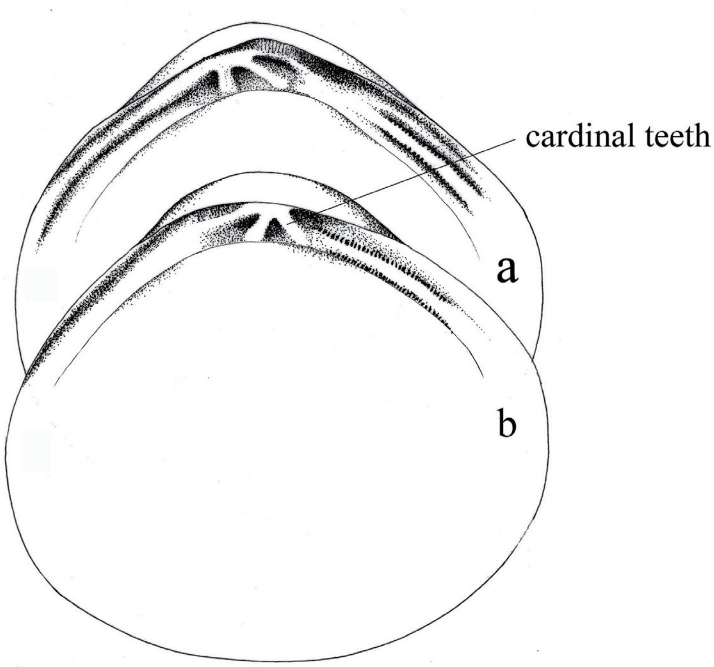


Fig. 14 Left valve (a) and right valve (b) of *Corbicula* sp.

Fig. 15 Shell bed of freshwater mussels in the Pong River.

The following keys for Pelecypoda are modified from Brandt (1974).

Class Gastropoda

Key to Subclasses, Orders and Families of Gastropoda of Indochina

1 Shell with an operculum .... Subclass Prosobranchia...2
1′ Shell without operculum ....Subclass Pulmonata...8

2(1) Shell siphonate (Fig. 16)............................Order Neogastropoda, Buccidae, *Clea*
2′ Shell not siphonate, radula with 2 teeth in one row....... Order Mesogastropoda...3

3(2′) Male with verge (Fig. 9); shell smaller than 20 mm... 4
3′ Male without verge; shell larger than 20 mm 6

4(3) Operculum concentric (Fig. 4c-d) ....Bithyniidae (p. 54)
4 Operculum spiral (Fig. 4a-b) 5

5(4′) Inner surface of operculum with ridges; aperture constricted; basal whorl swollen .. ..Stenothyridae (p. 55)
5′ Inner surface of operculum without ridges; aperture not constricted; basal whorl not swollen... Hydrobiidae (p. 55)

6(3′) Male with intromittent organ (Fig. 1).. 7
6′ Male without intromittent organ ....Thiaridae (p. 59)

7(6) Shell generally smaller than 40 mm; operculum not nacreous, corneous; male right tentacle transformed into male intromittent organ, ovoviviparous ....Viviparidae (p. 60)
7′ Shell generally larger than 40 mm; operculum nacreous, not calcareous; pseudoverge at the pallial edge; oviparous .... Pilidae (Ampulariidae) (p. 61)

8(1) Shell cap-like (Fig. 7) .... Ancylidae (p. 62)
8′ Shell not cap-like or discoidal; dextral (Fig. 7)... 9

9(8) Shell discoidal .... Planorbidae (p. 62)
9′ Shell not discoidal, shell thin, dextral.. Lymnaeidae (p. 62)

Key to Genera and Species of Bithyniidae

1 Peristome sinuate (Fig. 17a) .... *Wattebledia*...2
1′ Peristome not sinuate (Fig. 18a)..*Bithynia*...3

2(1) Shell dull, whorls slightly convex .... *crosseana*
2′ Shell glossy, whorls very convex (Fig. 18) .... *siamensis*

3(1′) Umbilicus funnel-shaped, carina strong ....f*uniculata*
3 Umbilicus very narrow, carina weak or missing ....*siamensis*

Key to Species of Family Stenothyridae

There is one genus, *Stenothyra*

1 Shell with spiral ridges .... *spiralis*
1′ Shell without spiral ridges 2

2(1′) Shell with microsculpture 3
2′ Shell without microsculpture 4

3(2) Microsculpture on the last quarter of the body whorl; base of body whorl with pitted spiral lines .... *basisculpta*
3′ Microsculpture on all whorls, only nuclear whorls with pitted spiral lines .... *microsculpta*

4(2′) Shell with macrosculpture 5
4′ Shell without macrosculpture 8

5(4) Sculpture only on the upper whorls 6
5′ Sculpture on all whorls .... *roseni*

6(5) Shell ovate-conoidal ....*koratensis*
6′ Shell ovoidal or subglobose 7

7(6′) Shell ovoidal ....*ovalis*
7′ Shell subglobose .... *crooki*

8(4′) Neck with distinct brown patch 9
8′ Neck without brown patch 10

9(8) Shell ovoidal with conic spire ....*fasciata*
9′ Shell pupaeform with dome-shaped spire .... *wykoffi*

10(8′) Shell ovate-conoidal ....*jiraponi*
10′ Shell ovoidal or ovate 11

11(10′) Apex flattened, aperture exerrated..*hybocystoides*
11′ Apex dome-shaped, aperture not exerrated 12

12(11′) Shell smaller than 2.5 mm, aperture straight..................................... *cambodiensis*
12′ Shell larger than 3.0 mm, aperture oblique...*mcmulleni*

KEY TO SUBFAMILIES, GENERA AND SPECIES OF HYDROBIIDAE

1 Verge simple, without appendages (Fig. 9b); shell ovate (Fig. 19) .... REHDERIELLINAE, *Rehderiella parva*
1′ Verge with 1-2 appendages 2

2(1′) Animal with yellow pigmentation; shell larger than 10 mm .... LITHOGLYPHINAE 3
2′ Animal without yellow pigmentation; shell small, not larger than 5 mm. (Fig. 20) .. ..TRICULINAE, *Neotricula*

3(2) Shell neritoid (Fig. 21) ....*Lacunopsis* 4
3′ Shell not neritoid 9

4(3) Septum narrow, ventral part of body whorl round... 5
4′ Septum and ventral part of body whorl form a large plain which is bordered by a sharp carina 7

5(4) Shell with tubercles or spines (Fig. 8e) 6
5′ Shell without tubercles or spines .... *munensis*

6(5) Shell with few scaly spines ....*coronata*
6′ Shell with several obtuse ubercles...*levayi*

7(4′) Shell diameter less than 10 mm.. 8
7′ Shell diameter larger than 10 mm..*fischerpiettei*

8(7) Shell with scaly spines... *massiei*
8′ Shell wih out spines or tubercles .... *harmandi*

9(3) Shell smooth or with axial sculpture (Fig. 8b) 10
9′ Shell with spiral sculpture (Fig. 8d) 36

10(9) Peristome sharp or with thin lip... 11
10 Peristome with very thick lip 28

11(10) Sculptured with axial ribs: outer margin of peristome sinusoid (Fig. 22)................ ....*Hubendickia*...12
11′ Shell smooth; peristome not sinusoid.. 21

12(11) Shell larger than 5.2 mm 13
12′ Shell smaller than 5.0 mm 19

13(12) Sculptured only with axial ribs... 14
13′ Sculptured with axial ribs and/or tubercles 17

14(13) Spiral microsculpture prominent 15

14′ Spiral microsulpture obsolete .... *crooki*

15(14)Ribs rudimentary at the periphery, shell with 2 very weak keels on the upper half of the whorls .... *gochenouri*
15′ Ribs not rudimentary, shell without keel 16

16(15′) Apex homeostrophic (protoconch and teleconch are in the same direction), spiral sculpture very strong .... *spiralis*
16′ Apex alloistrophic (protoconch and teleconch are in the different direction), spiral sculpture moderately strong.. *siamensis*

17(13′) Shell with ribs and tubercles 18
17 Ribs dissolved into 2 spiral rows of tubercles .... *schuetti*

18(17) Subsutural groove separates a row of tubercles from the ribs................ *tuberculata*
18′ Shell with subsutural ridge which carries small sharp tubercles .... *coronata*

19(12′) Shell with spiral microsculpture... 20
19′ Shell without spiral microsculpture .... *cylindrica*

20(19) Ribs with 2 rows of tubercles; shell diameter not more than 1.6 mm...... *schlickumi*
20′ Ribs striate; shell diameter larger than 1.9 mm .... *cingulata*

21(11′) Shell ovate, ovate-conoidal or cylindrical; cutting edge of rhachis with several cusp... *Manningiella*…22
21′ Shell subglobose-conoidal; rhachis with simple, triangular cutting edge .... *Lithoglyphopsis aperta*

22(21) Shell with axial ribs.. *incerta*
22′ Shell without axial ribs or striae 23

23(22′) Peristome protracted below the columella .... *expansa*
23′ Peristome not protracted below the columella 24

24(23′) Shell with spiral microsculture... *microsculpta*
24′ Shell without spiral microsculture 25

25(24′) Shell cylindrical or ovate, corneous 26
25′ Shell conic .... *conica*

26(25) Shell ovate or ovoidal-conic.. *polita*
26′ Shell cylindrical or turreted 27

27(26′) Shell length less than 3.5 mm; width less than 1.5 mm .... *subulata*
27′ Shell length more than 5.5 mm; width more than 2.5 mm .... *pellucida*

28(10′) Shell smooth; rhachis with simple cutting edge (Fig. 23 ...... *Pachydrobiella brevis*
28′ Shell sculptured; rhachis with several cusps cutting edge (Fig. 24)..........................
....*Pachydrobia*...29

29(28′) Shell sculptured with axial ribs or striae 30
29′ Shell without axial sculptured ....*bavayi*

30(29) Back with tubercle or spine 31
30′ Back without tubercle or spine 35

31(30) Strong tubercle or spine... 32
31′ Weak tubercle or spine... 34

32(31) Back with tubercle.. 33
32′ Back with sharp spine..*spinosa*

33(32) Body whorl with pad-like ventro-lateral boss ....*zilchi*
33′ Body whorl without pad-like ventro-lateral boss ....*prasongi*

34(31′) Shell elongate, moderately thick ....*crooki*
34′ Shell stout, very thick ....*wykoffi*

35(30′) Shell with few strong ribs, larger than 10 mm ....*variabilis*
35′ Shell with many weak riblets, smaller than 10 mm...................................*munensis*

36(9′) Shell ovate-conoidal, subglobose conoidal or semispherical; lip extremely thick. 37
36′ Shell turreted or elongately conic; lip thin or moderately thick (Fig. 25) ....
....*Paraprososthenia*...47

37(36) Shell ovate-conoidal (Fig. 26).. *Hydrorissoia*...44
37′ Shell semispherical or subglobose conoidal 38

38(37′) Shell semispherical; columella compressed; rachis with simple cutting edge ....
....*Wykoffia*...43
38′ Shell subglobose-conoidal, columella not compressed; rachis with serrated cutting edge... (Fig. 27)..*Jullienia*...39

39(38′) Shell sculptured with several strong spiral ridges 40
39′ Shell sculptured with tubercles or few weak spiral ridges 41

40(39) Ventral face of body whorl flattened, 4 spiral ridges................................ *munensis*
40′ Ventral face of body whorl not flattened, 7 spiral ridges.................................. *acuta*

41(39′) Body whorl with 2 or 3 weak spiral ridges or rows of tubercles..............*harmandi*
41′ Body whorl at least 4 spiral ridges or tubercle rows 42

42(41′) Shell with weak, granulated spiral ridges.. *crooki*
42′ Shell with row of obtuse tubercles ....*prasongi*

43(38) Diameter of adult shell 3-4 mm.. *minima*
43′ Diameter of adult shell 5-5.6 mm ....*costata*

44(37) Small size, shell length less than 3.6 mm; width less than 2.3 mm; with 2-4 weak spiral ridge 45
44′ Large size, shell length more than 4 mm; width more than 2.3 mm, with 5-6 strong spiral ridges...*elegan*

45(44) Spire cylindrical, aperture less than half the length of the shell ....*gracilis*
45′ Spire conic, aperture half the size of shell or more 46

46(45′) Shell ratio 7:4, height of aperture about half of shell, aperture not exserted .... *munensis*
46′ Shell ratio 3:2, height of aperture more than half of shell, aperture prominent exserted .... *trispiralis*

47(36′) Conical shell, with 4-5 spiral rows of tubercles; peristome simple.............*hanseni*
47′ Shell turreted, with spiral ridges on the whole shell or with spiral rows of tubercles on the upper half of the whorls and spiral ridges on the lower half 48

48(47′) Shell with spiral ridge only 49
48′ Shell with spiral tubercles on the upper half of body whorl and with spiral ridge on the lower half of body whorl 51

49(48) Shell larger than 8.5 mm; with 4 strong spiral ridges, outer margin of peristome protruding (Fig. 28) ....*Kareliania*
49′ Shell smaller than 8 mm; with 6-7 spiral ridges, outer margin of peristome not protruding 50

50(49′) Peristome simple ....*davisi*
50′ Peristome reflected and flattened...*taylori*

51(48′) Base with periomphalic ridge...*iijmai*
51′ Base without periomphalic ridge...*levaeyi*

Key to Subfamilies, Genera and Species of Thiaridae

1 Operculum paucispiral (Fig. 4a)... THIARINAE…2
1′ Operculum multispiral (Fig. 4b)... MELANATRINAE…4

2(1) Shell ovate-conoidal, moderately long or short spire, body whorl shouldered, upper half with ribs, whorls rounded with delicate spiral ridges (Fig. 29).... *Thiara scabra*

2′ Shell conic or turreted, spire often eroded, body whorl not shoulder; shell with axial ribs (Fig. 30) ....*Melanoides*...3

3(2′) Whole whorl sculptured with spiral lines; weak axial ribs......................*tuberculata*
3′ Base of body whorl sculptured with spiral line; strong axial ribs ....*jugicostis*

4(1′) Shell with axial brown flames (Fig. 31) ....*Ademietta bousei*
4′ Shell unicoloured or with spiral bands 5

5(4′) Shell ovate-conoidal (Fig. 32); oval operculum with lateral nucleus........................ ....*Paracrostoma solemiana*
5′ Shell turreted (Fig. 33); round operculum with central nucleus (Fig. 4b0 ....*Brotia*...6

6(5′) Shell with spines or tubercles ....*pseudoasperata*
6′ Shell without spines or tubercles 7

7(6′) Shell with spiral macrosculpture ....*citrina*
7′ Shell without spiral macrosculpture, shell diameter less than 20 mm..................... 8

8(7′) Shell larger than 35 mm... *maningi*
8′ Shell smaller than 35 mm .... *insolita*

Key to Genera and Species of Viviparidae

1 Shell with colour bands (Fig. 34-35).. *Filopaludina*...2
1′ Shell without colour bands (Fig. 36-40)... 5

2(1) Adult shell green coloured, strong colour band; spiral bands raised on the upper whorls (Fig. 34) ....*Filopaludina (Filopaludina)*...3
2′ Adult shell olive or brownish coloured, colour bands weak; spiral bands not raised on the upper whorls (Fig. 35) .... *Filopaludina (Siamopaludina)*...4

3(2) With four colour bands between suture and periphery .... *sumaterensis*
3′ With two colour bands between suture and periphery...................................*filosa**

4(2′) Upper whorls with colour bands... *martensi*
4′ Upper whorls with two strong coloured spiral ridges................................*maekoki**

5(1′) Shell depressed-conic, peripheral keel and shell without spiral ridge (Fig. 36) ....*Trochotaia trochoides*
5′ Shell subglobose or ovoidal... 6

6(5′) Shell smooth or with weak ridges (Fig. 37,38), embryonic shell without peripheral keel... 7
6′ Shell with strong ridges (Fig. 39,40), embryonic shell with peripheral keel 13

7(6) Shell ovate, thin (Fig. 37) .... *Idiopoma*...8
7 Shell subglobose, rather thick (Fig. 38)... *Mekongia*...9

8(7) Umbilicus closed or moderated opened, not surrounded by a strong carina, whorls very convex.. *dissimilio*
8′ Umbilicus funnel shaped, surrounded by a strong carina, shell with spiral line .... *umbilicata*

9(7′) Apical whorls dark violet 10
9′ Apical whorls not violet 12

10(9) Adults shell not larger than 20 mm (Fig. 38).. *pongensis*
10′ Adults shell larger than 25 mm.. 11

11(10′) Shell elongate, last whorl twice as high as penultimate whorl.................. *lamarcki*
11′ Shell subglobose, last whorl three as high as penultimate whorl .... *sphaericula*

12(9′) Shell subglobose, umbilicus closed .... *swainsoni*
12′ Shell ovate-conoidal, umbilicus opened .... *ratteri*

13(6) Shell turreted (Fig. 39).. *Sinotaia*...14
13′ Shell subglobose (Fig. 40) .... *Anulotaia*...15

14(13) Spiral ridge obtuse... *mandablbarthi*
14′ Spiral ridge sharp.. *auturrolli*

15(13′) Strong spiral ridges.. *forcarti*
15′ Weak spiral ridges.. *mekongensis*

* found in Mae Kok River

Key to Genera and Species of Pilidae (Ampullariidae)

1 Shell ovoidal conic or subglobose; suture deep; ovoidal aperture (Fig. 42-44)......... .... *Pila*...2
1′ Shell globose; suture shallow; round aperture (Fig. 41)............................ *Pomacea*

2(1) Shell ovoidal, periderm very glossy, inner surface of operculum steel-blue (Fig. 42) .... *polita*
2′ Shell conical or subglobose, periderm moderately glossy, inner surface of operculum whitish-nacreous.. 3

3(2′) Shell subglobose 4
3′ Shell ovate conical, shell thin; without bands (Fig. 43) .... *scutata*

4(3) Shell with a thin white lip.. *ampullacea*
4′ Shell with a thick orange lip (Fig. 44) .... *pesmi*

Family Ancylidae (Fig. 45)

Only one species found, *Ferrissia baconi.* Shell cap-shaped, round-trapezoidal outline; apex conical, with radiating striate; symmetric rhachis, aperture large, attached on stone or vegetation.

Family Lymnaeidae (Fig. 46)

Only one species found, *Lymnaea (Radix) auricularia*. Shell ovate or ovoidal-conic, dextral, thin, with short conic spire and large inflated body whorls; corneous, translucent, no sculpture; aperture large, ovate; sharp thin peristome.

Family Planorbidae (Fig. 47)

Only one species found, *Indoplanorbis exustus*. Shell discoidal, upper and lower side concave, with regular fine axial riblets; aperture large, sharp peristome without lip.

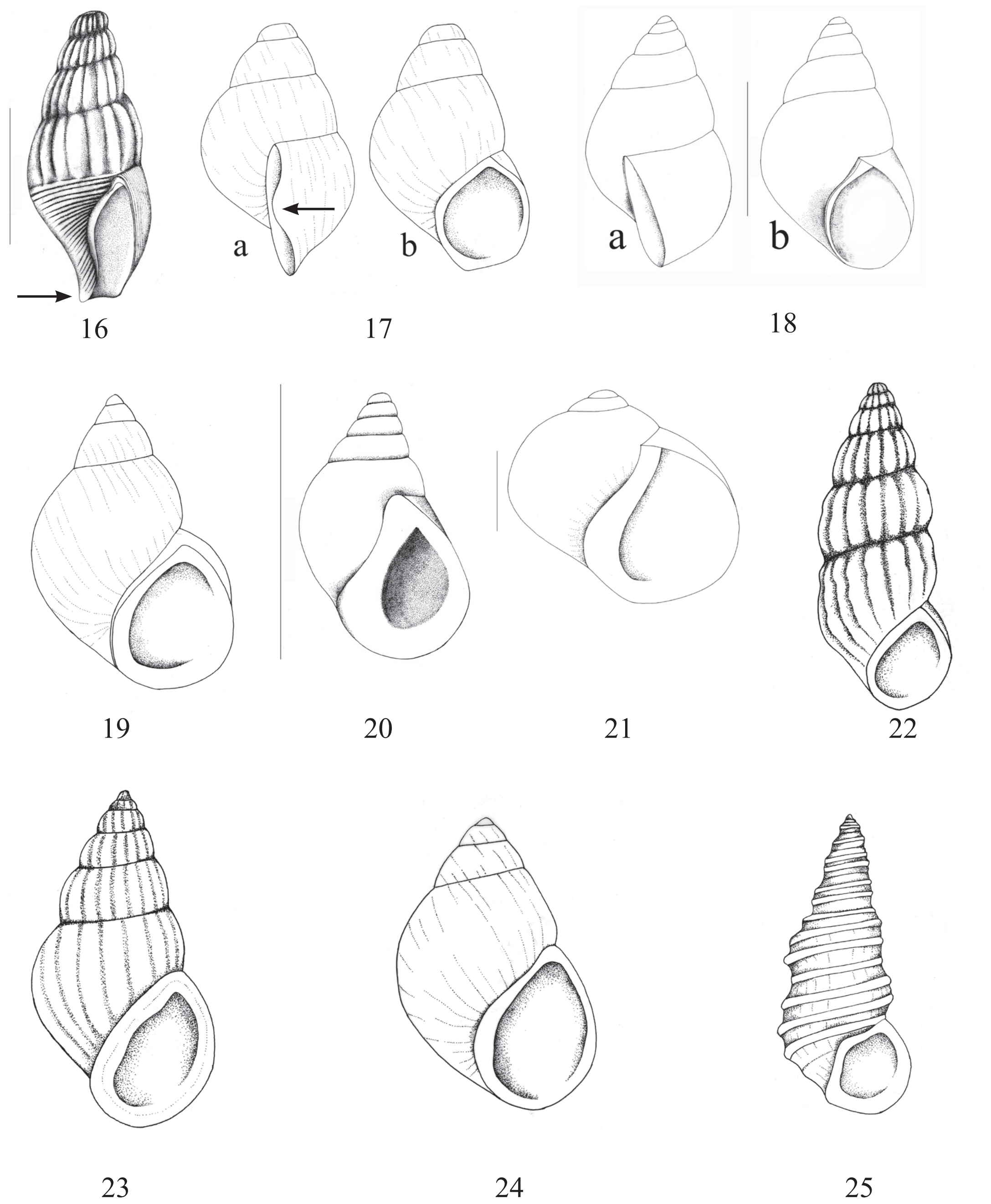


Fig. 16-25 16. Shell of *Clea* sp. (arrow indicated siphonate); 17. Side view (a) and apertural view (b) of shell of *Wattebledia* sp. arrow indicates sinuosity (redrawn from Upatham *et al*., 1983, fig. 52a-b); 18. Side view (a) and apertural view (b) of shell of *Bithynia siamensis*; 19. Shell of *Rehderiella* sp. (redrawn from Upatham *et al*., 1983, fig. 63); 20. Shell of *Neotricula aperta*; 21. Shell of *Lacunopsis* sp.; 22. Shell of *Hubendickia* sp. (redrawn from Upatham *et al*., 1983, fig. 72); 23. Shell of *Pachydrobiella* sp. (redrawn from Upatham *et al*., 1983, fig.70); 24. Shell of *Pachydrobia* sp. (redrawn from Upatham *et al*., 1983, fig. 71); 25. Shell of *Paraprososthenia* sp. (redrawn from Upatham *et al*., 1983, fig. 69).
Scale = 5 mm.

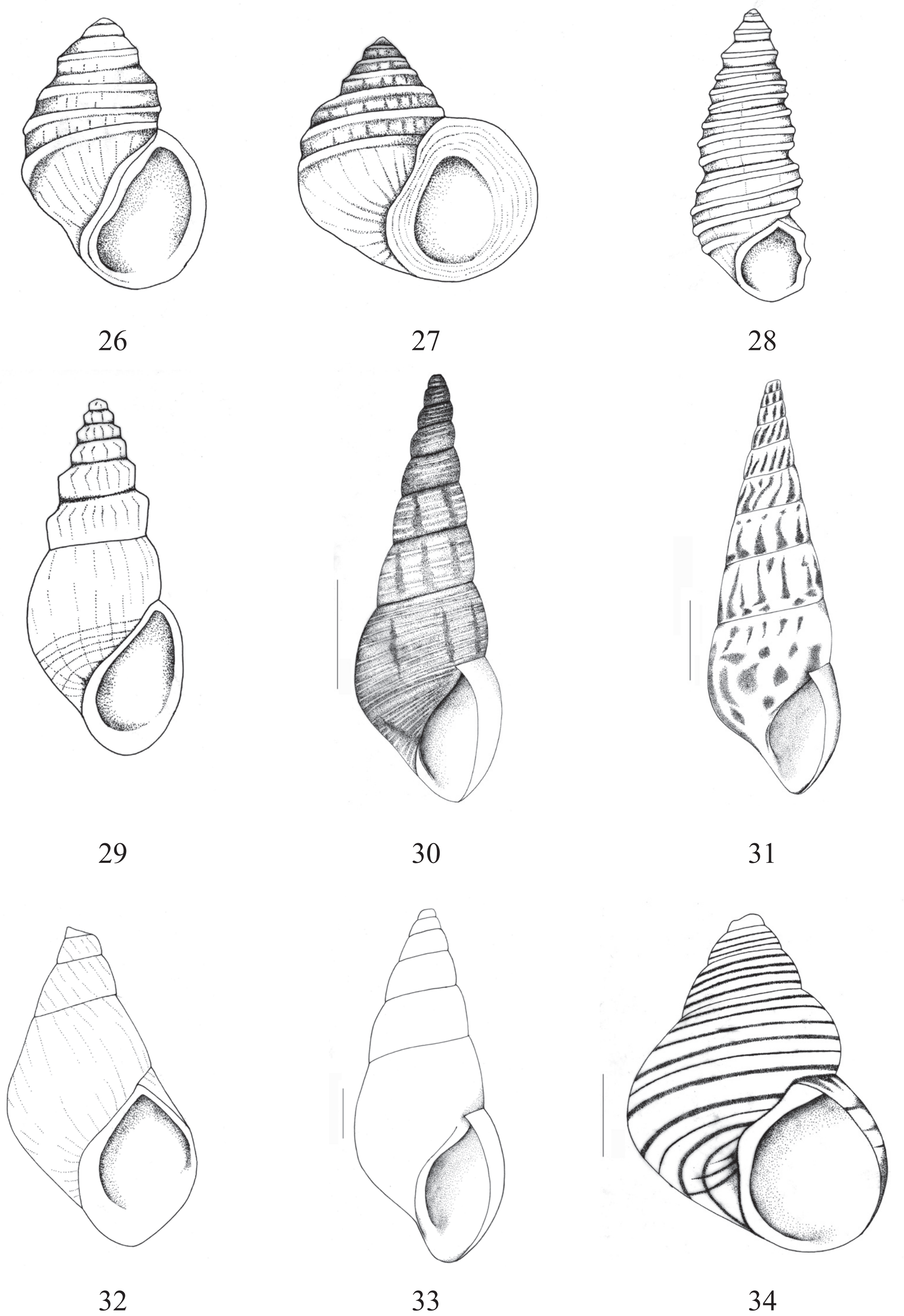


Fig. 26-34 26. Shell of *Hydrorissoia* sp. (redrawn from Upatham *et al*., 1983, fig. 67); 27. Shell of *Jullienia* sp. (redrawn from Upatham *et al*., 1983, fig. 65); 28. Shell of *Kareliania* sp. (redrawn from Upatham *et al*., 1983, fig. 68); 29. Shell of *Thiara* sp. (redrawn from Upatham *et al*., 1983, fig. 76); 30. Shell of *Melanoides* sp.; 31. Shell of *Ademietta* sp.32. Shell of *Paracrostoma* sp. (redrawn from Upatham *et al*., 1983, fig. 75); 33. Shell of *Brotia* sp.; 34. Shell of *Filopaludina* (*Filopaludina*) sp.
Scale = 5 mm.

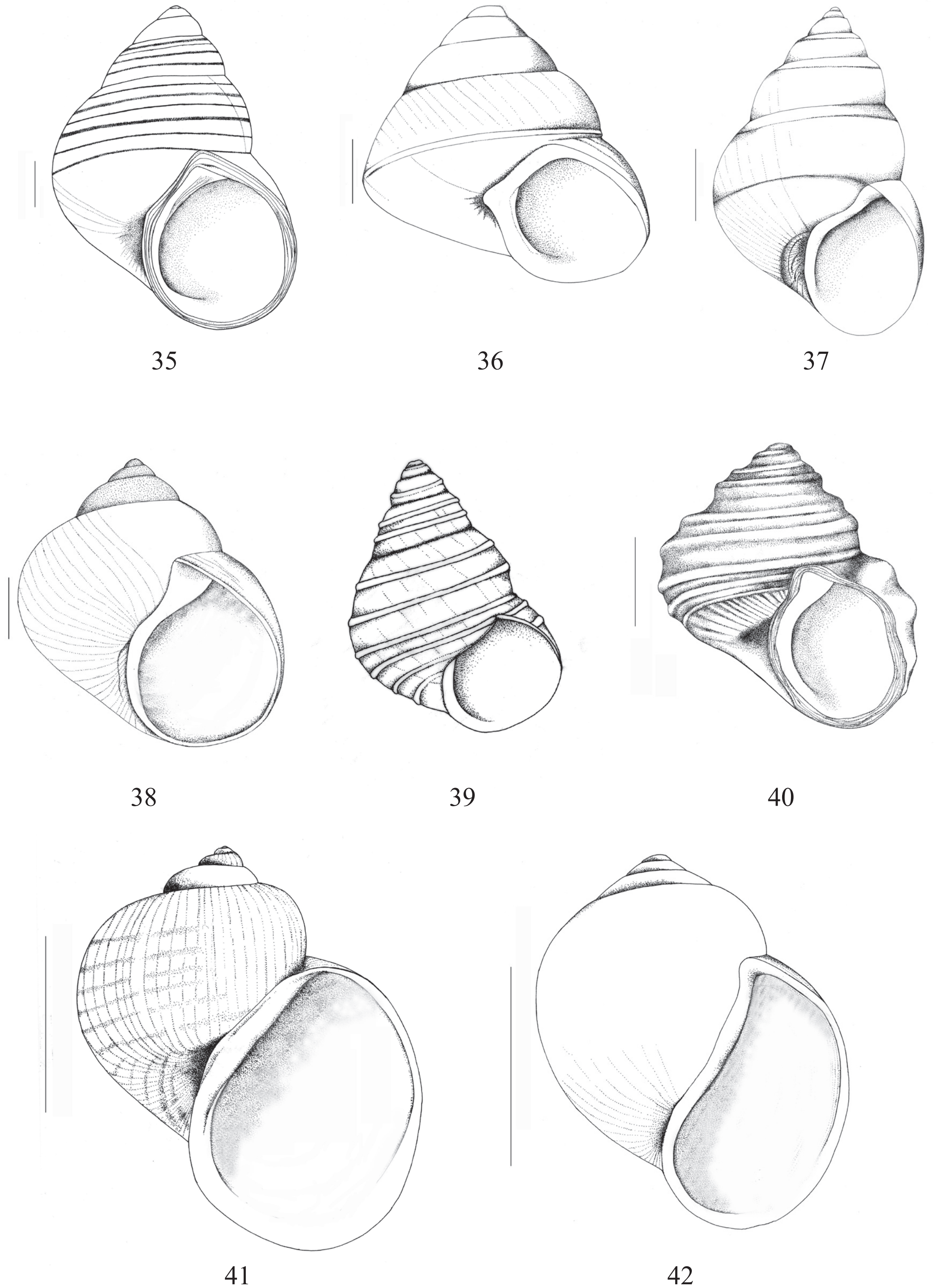


Fig. 35-42 35. Shell of *Filopaludina* (*Siamopaludina*) sp.; 36. Shell of *Trochotaia trochoides*; 37. Shell of *Idiopoma* sp.; 38. Shell of *Mekongia pongensis*; 39. Shell of *Sinotaia* sp. (redrawn from Upatham *et al*., 1983, fig. 40); 40. Shell of *Anulotaia* sp.; 41. Shell of *Pomacea* sp.; 42. Shell of *Pila polita*. Scale: (35-40) 5 mm; (41-42) 5 cm.

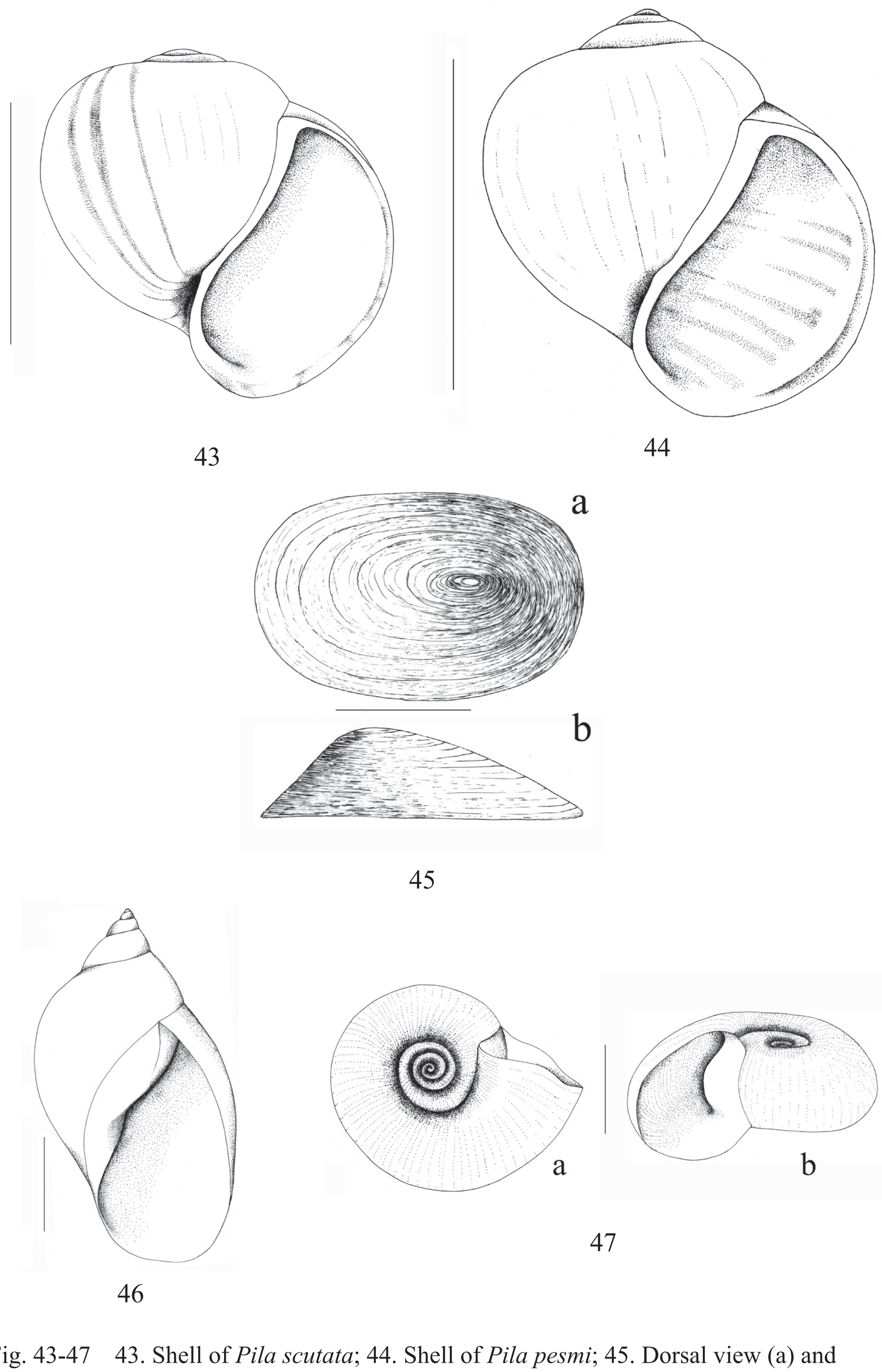


Fig. 43-47 43. Shell of *Pila scutata*; 44. Shell of *Pila pesmi*; 45. Dorsal view (a) and lateral view (b) of the shell of *Ferrissia baconi*; 46. Shell of *Lymnaea* (*Radix*) *auricularia*; 47. Dorsal view (a) and lateral view (b) of the shell of *Indoplanorbis exustus*.
Scale: (43-44) 5 cm; (45-47) 5 mm.

Class Pelecypoda

Key to Subclasses, Orders and Families of Bivalvia of Indochina

1 Hinge teeth (if present) modified into cardinals and laterals (Fig. 52b, 58b); mantle edge ventrally united 2

1′ Hinge teeth (if present) not modified into cardinals and laterals (Fig. 48a); mantle edge ventrally opened .... Subclass Pteriomorphia...3

2(1) Teeth with true cardinals (Heterodont hinge) (Fig. 14,58b) .... Subclass Heterodonta...4

2′ Teeth without true cardinals (Schizodont hinge); anterior lamella transformed into pseudocardinals (Fig. 52b) ....Subclass Schizodontida, Amblemidae (p. 67)

3(1′) Hinge with many equally shaped teeth (Fig. 48a); animal with anterior adductor .... Order Arcoida, Arcidae, *Scaphula*

3′ No hinge teeth; animal without anterior adductor (Fig. 57b) ....Order Mytiloida, Mytiliidae (p. 69)

4(2) Hinge teeth with laterals (Fig. 58b) 5

4′ Hinge teeth without laterals and cardinals.................................Dreissenidae (p. 69)

5(4) Hinge teeth with 3 cardinals in each valve (Fig. 58); with veliger larvae................. ....Corbiculidae (p. 69)

5′ Hinge teeth with 1 or 2 cardinals in each valve; ovoviviparous................................ .... Sphaeriidae (p. 69)

Key to Subfamilies, Genera and Species of Amblemidae

1 Hinge with lateral teeth (Fig. 52b).. 2

1′ Hinge without lateral teeth (Fig. 55b, 56b) .... Pseudodontinae...20

2(1) Pseudocardinals lamelliform (Fig. 53b) .... Rectidentinae...13

2′ Pseudocardinals dentiform (Fig. 52b) or obsolete.. 3

3(2′) Shell winged (Fig. 51); shell length more than 100 mm ....Hyriopsinae...10

3′ Shell not winged; shell length less than 80 mm .... Parreysiinae...4

4(3′) Shell inflated, oval or cuneiform 5

4′ Shell not inflated, rhomboidal ....*Harmandia munensis*

5(4) Shell short, oval-semicircular...*Unionetta fabagina*

5′ Shell elongately oval or cuneiform.. 6

6(5′) Pseudocardinals tooth-shaped (Fig. 50b)...*Scabies*...8

6′ Pseudocadinals compressed...*Indonaia*...7

7(6′) Shell length less than 30 mm; sculpture on the umbones and on the upper half of the shell.. *humilis*
7′ Shell length more than 40 mm; without sculpture on the shell ....*pilata*

8(6) Shell elongately ovate or cuneiform; sculpture with 6 folds on 10 mm.................. 9
8′ Shell elongately reniform; sculpture with 9 folds on 10 mm ....*phaselus*

9(8) Shell length not more than 23 mm (Fig. 49)...*nucleus*
9′ Shell length at least 35 mm (Fig. 50)...*crispata*

10(3) Hinge with pseudocardinals (Fig. 51b,52b).. 11
10′ Hinge without pseudocardinals .... *Cristaria plicata*

11(10) Shell elongate; with small anterior wing and large posterior wing (Fig. 51)........... ....*Hyriopsis*...12
11′ Shell suborbicular; with posterior wing only (Fig. 52) .. *Chamberlainia hainesiana*

12(11) Shell height less than half of length (without wing) .... *bialatus*
12′ Shell height more than half of length (without wing) ....*delaportei*

13(2) Hinge teeth weak (Fig. 54b) 16
13′ Hinge teeth strong (Fig. 53b).. 14

14(13′) Shell ovate; with umbonal sculpture ....*Uniandra*...15
14′ Shell cuneiform; without umbonal sculpture (Fig. 53)........... *Ensidens ingallsianus*

15(14) Shell subcircular shape; length less than 30 mm................................ *subcircularis*
15′ Shell more or less ovate-elongate, but never subcircular; length more than 35 mm.. .... *contradens*

16(13) Shell compressed...*Trapezoideus comptus*
16′ Shell more or less inflated (Fig. 54) .... *Physunio*...17

17(16′) Shell trapezoidal, compressed (Fig. 54) 19
17′ Shell ovate, moderately inflated 18

18(17′) Shell with distinct wing and oblique dorsal margin; lateral margin strong, diverging...*inornatus*
18′ Shell without distinct wing; dorsal margin parallel to ventral; lateral thin, parallel .. .. *modelli*

19(17) Wing higher than 30 mm, laterally distinct, diverging (Fig. 54)..................*eximius*
19′ Wing not higher than 30 mm, laterally very thin, parallel................... *cambodiensis*

20(1′) Shell hook-shaped ....MODELLNAIINAE, *Modellnaia siamensis*
20′ Shell not hook-shaped (Fig. 55,56) .... PSEUDODONTINAE...21

21(20′) Hinge with one knob-like pseudocardinal in each valve (Fig. 55b) ....
.... *Pseudodon*…22
21′ Hinge without any teeth (Fig. 56b)..*Pilsbryoconcha exilis*

22(21) Shell not reniform.. 23
22′ Shell reniform .... *mouhoti*

23(22) Shell rounded-trigonal, with posterior wing ....
.... *cambodiensis*
23′ Shell oval, thick, without posterior wing (Fig. 55).. 24

24(23′) Shell high posteriorly and greatly inflated (Fig. 55) ....*vondembuschianus*
24′ Shell not raised posteriorly and moderately inflated .... *inoscularis*

Key to Genera and Species of Mytilidae

1 Shell with radial sculpture; ligament with tubercles ....*Brachidontes*
1′ Shell without radial sculpture; ligament without tubercles (Fig. 57) ....
....*Limnoperna*…2

2(1′) Small size shell length less than 8 mm .... *supoti*
2′ Larger size, shell length more than 10 mm..*siamensis*

Family Dreissenidae

Only one genus, *Sinomytilus*, was found.

Key to Species of Sinomytilus

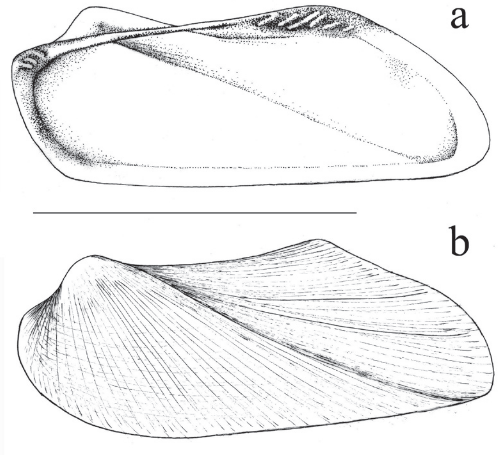
1 Shell length more than 20 mm; shell elongate, not equilateral, with pointed anterior end and round posterior .... *S. hamandi*
1′ Shell length less than 10 mm; shell elongate triangular .... *S. morrisoni*

Family Corbiculidae (Fig. 58)

There is only one genus, *Corbicula*. Shell rounded, triangular or cardiiform, hinge with 3 cardinals in each valve. Sculpture with concentric ribs or striae of difference strength. Interior of shell bluish-violet, rarely whitish or another colour.

Family Sphaeriidae

There is only one species, *Pisidium clarkeanum*. Shell very small, obliquely ovate, greatly inflated. Shell with external ligament, shell glossy



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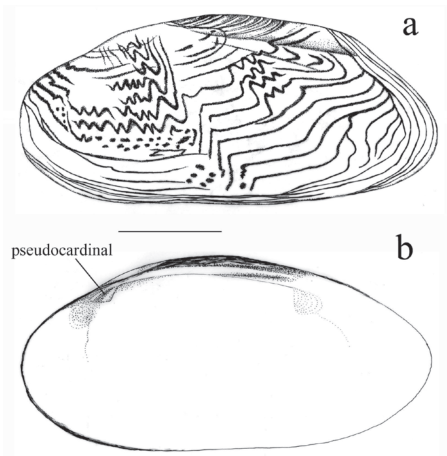

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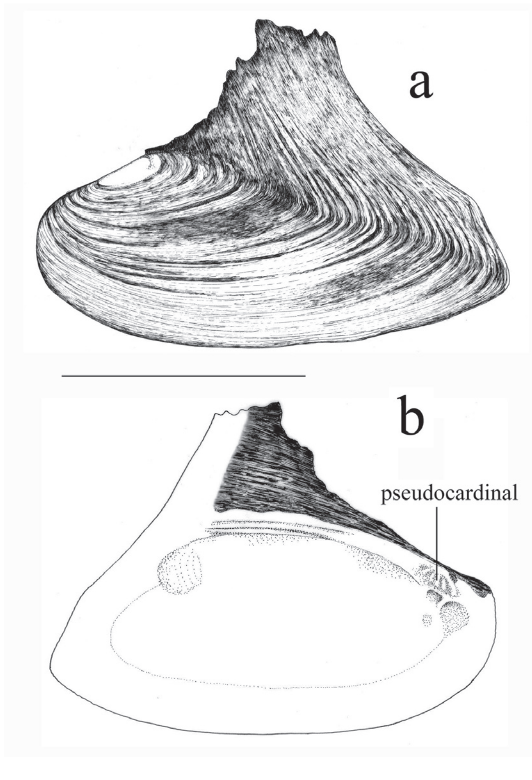

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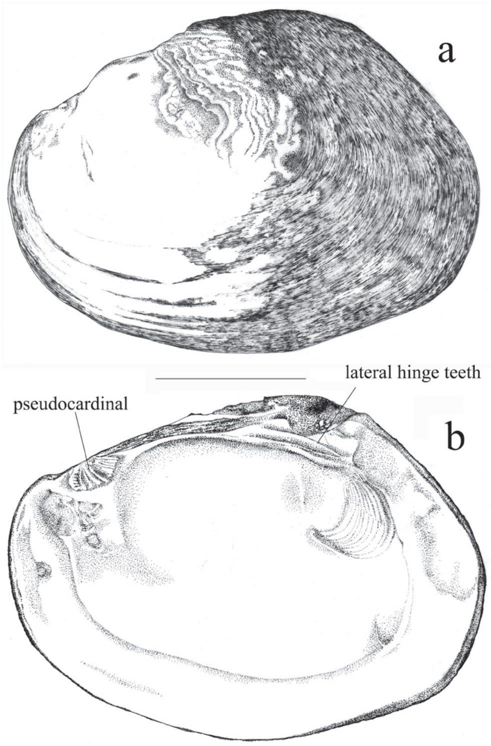
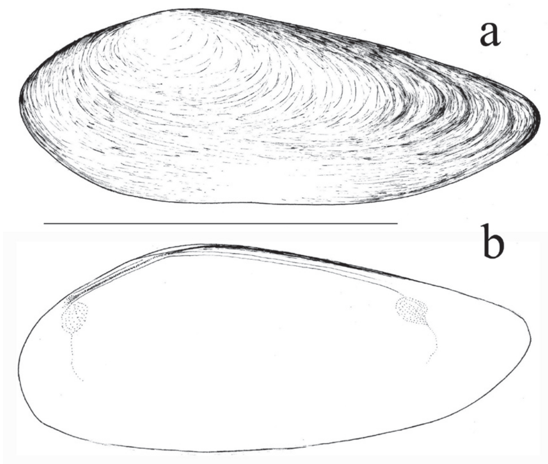
Fig. 48–51 48. Left valve (a) and right valve (b) of the shell of *Scaphula* sp.; 49. Shell of *Scabies nucleus.* 50. Left valve (a) and right valve (b) of the shell of *Scabies crispata*; 51. Left valve (a) and right valve (b) of the shell of *Hyriopsis* sp. Scale: (48-50) 5 mm; (51) 5 cm.





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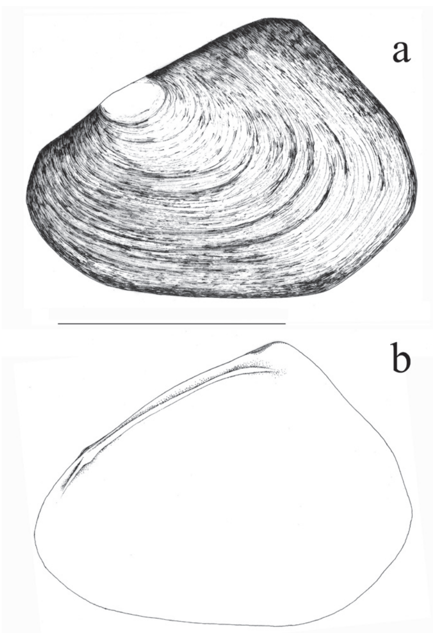

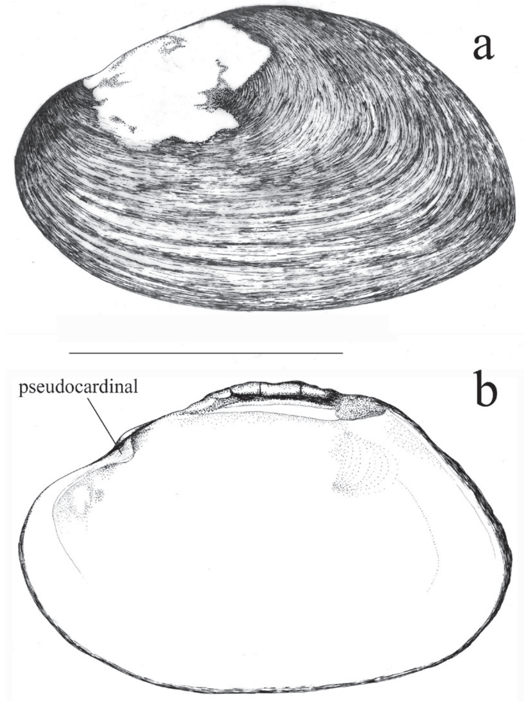

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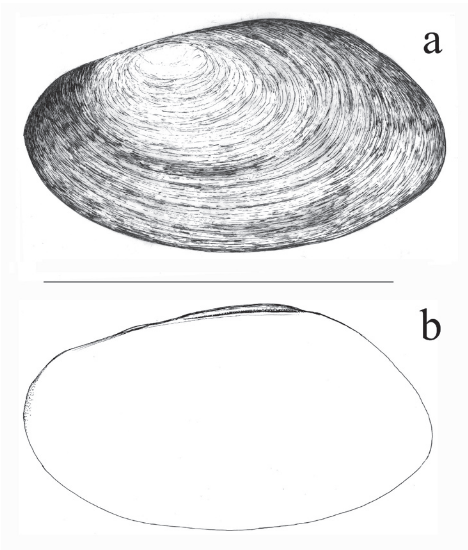
Fig. 52–55 52. Left valve (a) and right valve (b) of the shell of *Chamberlainia hainesiana*; 53. Left valve (a) and right valve (b) of the shell of *Ensidens ingallsianus*; 54. Left valve (a) and right valve (b) of the shell of *Physunio eximius*; 55. Left valve (a) and right valve (b) of the shell of *Pseudodon vondembuschianu*s. Scale = 5 cm.



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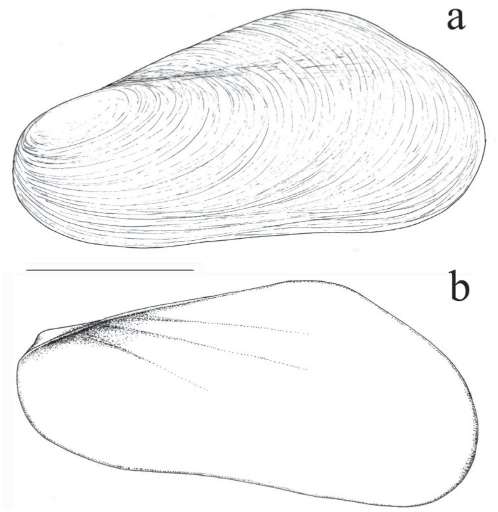

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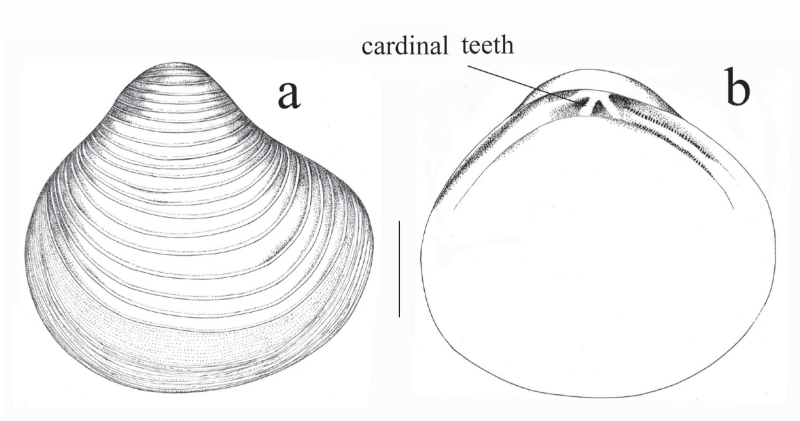

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Fig. 56-58 56. Left valve (a) and right valve (b) of the shell of *Pilsbryoconcha exilis*;
57. Left valve (a) and right valve (b) of the shell of *Limnoperna siamensis*;
58. Left valve (a) and right valve (b) of the shell of *Corbicula* sp.
Scale: (57) 5 mm; (56,58) 5 cm.

Chapter 11 Phylum Arthropoda

Arthropods are eucoelomate protostomes with well-developed organ systems. Their unique characteristic is a chitinous **exoskeleton** that is moulted (shed) at intervals to increase the body size. Arthropods colonise all types of habitat, even the house and garden. The group includes spiders, scorpions, ticks, mites, insects, crustaceans, millipedes and centipedes.

General structure and function

Arthropods have achieved a great diversity and abundance due to their various adaptations. They have metameric segmentation, segments grouped into tagmata (head and trunk; head, thorax and abdomen, or cephalothorax and abdomen), and **jointed appendages**, which are often modified for specialized functions.

The muscular system is complex and well-developed, with both striated and smooth muscles. The digestive system is complete. Many of the anterior appendages are modified to form mouth parts adapted for different feeding methods. Gas exchange occurs across the body surface, gills, trachea or book lungs. The coelom is reduced; most of the body cavity, composed of sinuses or spaces in the tissue (called the hemocoel), is filled with hemolymph. Thus they have an open circulatory system, with a dorsal contractile heart, arteries and hemocoel. The excretory system varies depending on the type of arthropod. Crustaceans have a pair of excretory glands, the antennal or maxillary glands. Insects, millipedes and centipedes have malpighian tubules, and many insects also posses nephrocytes which phagocytize waste particles. The nervous system has a dorsal brain connected by a ring around the esophagus to a double nerve chain of ventral ganglia. Sensory organs are well-developed.

Arthropods are dioecious, with paired reproductive organs and ducts. They usually have internal fertilization, and are oviparous, ovoviviparous or viviparous. A few arthropods have parthenogenesis. They usually have metamorphosis through their life cycle.

Arthropods are found in nearly all types of habitats. Their great diversity, abundance and wide distribution results from the following physiological and structural adaptations.

1. A hardened skeleton

The cuticle of arthropod is a hard external skeleton, or exoskeleton, which is light, flexible and highly protective without sacrificing mobility. It is made of protein and chitin components which are insoluble in water, alkaline solutions and weak acids. To grow, an arthropod must shed the exoskeleton at intervals and grow a larger new one. Before the new exoskeleton hardens, land arthropods enlarge it by swelling with air, while aquatic arthropods swell it with water.

2. Tagmata and appendages

Each segment of arthropods usually has a pair of jointed appendages. But body segments can become reduced in number, grouped or fused in various way, to support more specialized functions. For example, in shrimps, different segments are combined to form the cephalothorax and abdomen. In insects, segments are combined to form a head, thorax and abdomen. The jointed appendages are equipped with sensory setae, and have been modified for sensing, feeding, walking, swimming, net spinning or transfering sex cells.

3. Respiratory structures

Most terrestrial arthropods have a highly efficient system of air tubes, or trachea, which can deliver oxygen directly to the tissues and cells. This makes high metabolic rates possible. Aquatic arthropods rely on gills or the body surface for gas exchange.

4. Highly developed sensory organs

In arthropods, sensory organs such as compound eyes and other sensory organs involved with touch, smell, hearing, balancing and chemical reception are well developed. These organs contribute greatly to the success of arthropods.

5. Reduced competition through metamorphosis

Many arthropods undergo metamorphosis, which involves various immature states and then, the adult. The structure of immatures differs from that of the adults. Thus the immatures can eat different kinds of food than the adult and occupy a different niche. This results in less competition within a species.

Ecological relationships and economic importance in the region

The arthropods are found in all types of habitats. Some species live on land, in freshwater, brackish and marine waters, and some are commensal or parasitic in living organisms. They are important components in aquatic food chains and play important roles in detrital processing and nutrient cycling in aquatic systems. Freshwater arthropods are used as food by many animals. Shrimps, crabs, and many aquatic insects are also sold as human food. Water fleas are important in aquaculture industries as food for rearing young fish and shrimp.

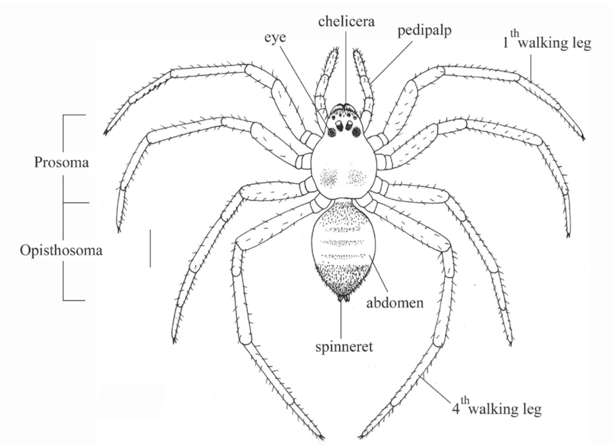
Classification

Members of the three subphyla Chelicerata, Crustacea and Uniramia are present in freshwater.

Chelicerate arthropods are an ancient group that includes horseshoe crabs, spiders, ticks and mites, scorpions and sea spiders. Among their common characteristics are six pairs of appendages (that include a pair of **chelicerae**, a pair of **pedipalps** and four pairs of walking legs) and a lack of antennae and mandibles.Fish spiders (order Araneae) live on water plants near margin of streams, rivers and ponds (Fig.1). They feed mostly on aquatic and terrestrial insects. After it bites and injects venom to kill its prey, the digested contents of the prey are suck out. Hydracarina, or water mites (order Acarina), differ from all other arachnids in having their cephalothorax and abdomen completely fused, and no sign of external segmentation (Fig.2). Many species are ectoparasites of aquatic insects and feed on their host's fluids.

The majority of crustaceans are aquatic and of economic importance. Crustaceans bear two pairs of antennae, a pair of mandibles, and two pairs of maxillae on the head, followed by a pair of appendages on most body segments. Except the first antennae, all appendages are biramous, which means having two branches. Crustaceans are diverse and abundant. They include crabs, shrimps, prawns, water fleas, isopods and amphipods. More details of crustaceans are available in Chapter 12.

Uniramia consists of class Chilopoda (millipedes), Diplopoda (centipedes) and Insecta (insects). Only some insects occur in freshwater. In general, the insect body is divided into three tagmata: head, thorax and abdomen. The thorax has three pairs of walking legs and one or two pairs of wings in the adult. Immature stages have no wings, or only wing pads are present in insects with incomplete metamorphosis. Gas exchange occurs across the body surface or through gills. Insects are the largest group of macroinvertebrates found in streams. Most have aquatic immature stages and they leave the water when they grow up into adults. But some spend their whole life cycle in the water. Details of aquatic and semiaquatic insect orders are available in chapters 13-25.



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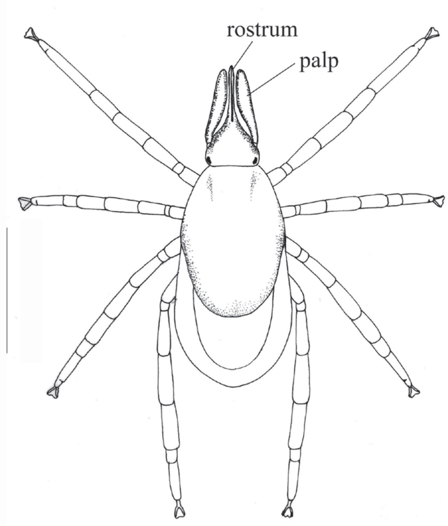

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Fig. 1-2 1. Dorsal view of a spider (Araneae); 2. Dorsal view of a water mite (Acarina) Scale = 1 mm.

Chapter 12 Freshwater Crustacea

The crustacean body consists of three tagmata: head, thorax and abdomen. A carapace may cover the head and thorax. In the head area there are two pairs of antennae and a pair of stalked eyes. Surrounding the mouth are three pairs of appendages that are involved in feeding or creating water currents for respiration—the mandibles and two pairs of maxillae. The eight thoracic segments have the first, second and third maxillipeds (which function on food manipulation) and five pairs of walking legs (or **pereopods**). The first three pairs of walking legs may be chelate and function in feeding or defence. The first five abdominal segments have swimmerets (or **pleopods**) that function in generating respiratory currents, and in the female they all are used for holding the eggs and developing young. The last pair of abdominal appendages, the **uropods**, are flat and wide appendages and are used as a rudder for swift backward movement (Fig. 1).

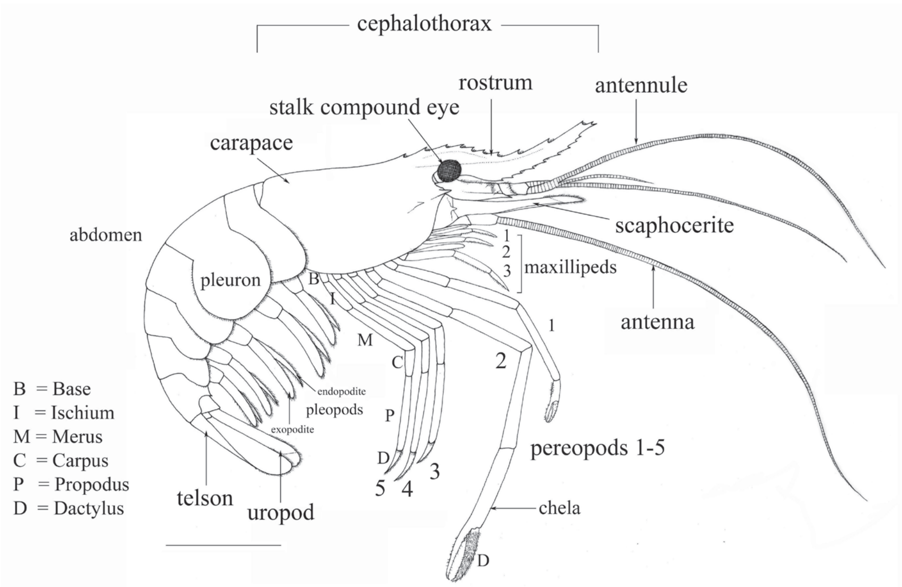


Fig. 1   Side view of female *Macrobrachium rosenbergii*.

There are three orders of crustaceans occurring in running water: Decapoda, Isopoda and Amphipoda. Decapoda includes crabs, shrimps and prawns. Shrimps (Atyidae) and prawns (Palaemonidae) have elongated bodies and appendages as previously mentioned. Atyidae are much smaller than Palaemonidae. They feed mainly on detritus. Unlike shrimps, crabs have a dorso-ventrally flattened carapace and a reduced abdomen which is folded under the carapace. External features of freshwater crabs are illustrated in Fig 2. Lotic crabs are in the families Gecarcinucidae, Potamidae and Parathelphusidae. The thicken and flattened carapace allows them to live in shelters under rocks. Some potamid crabs are intermediate hosts of the lung fluke (*Paragonimus* sp.) (Radomyos *et al*., 1992). Unlike the decapods, amphipods and isopods have no carapace, only one pair of maxilliped are present, and sessile compound eyes are present (some isopods lack eyes). Isopods are flattened dorso-ventrally and exchange gas through abdominal appendages, while amphipods are flattened laterally and have gills on the thorax, attached to the pereopods.

The following keys (to families of freshwater crabs and to species of freshwater prawns of the genus *Macrobrachium*) are modified from Ng (1988) and Cai *et al.* (2004).

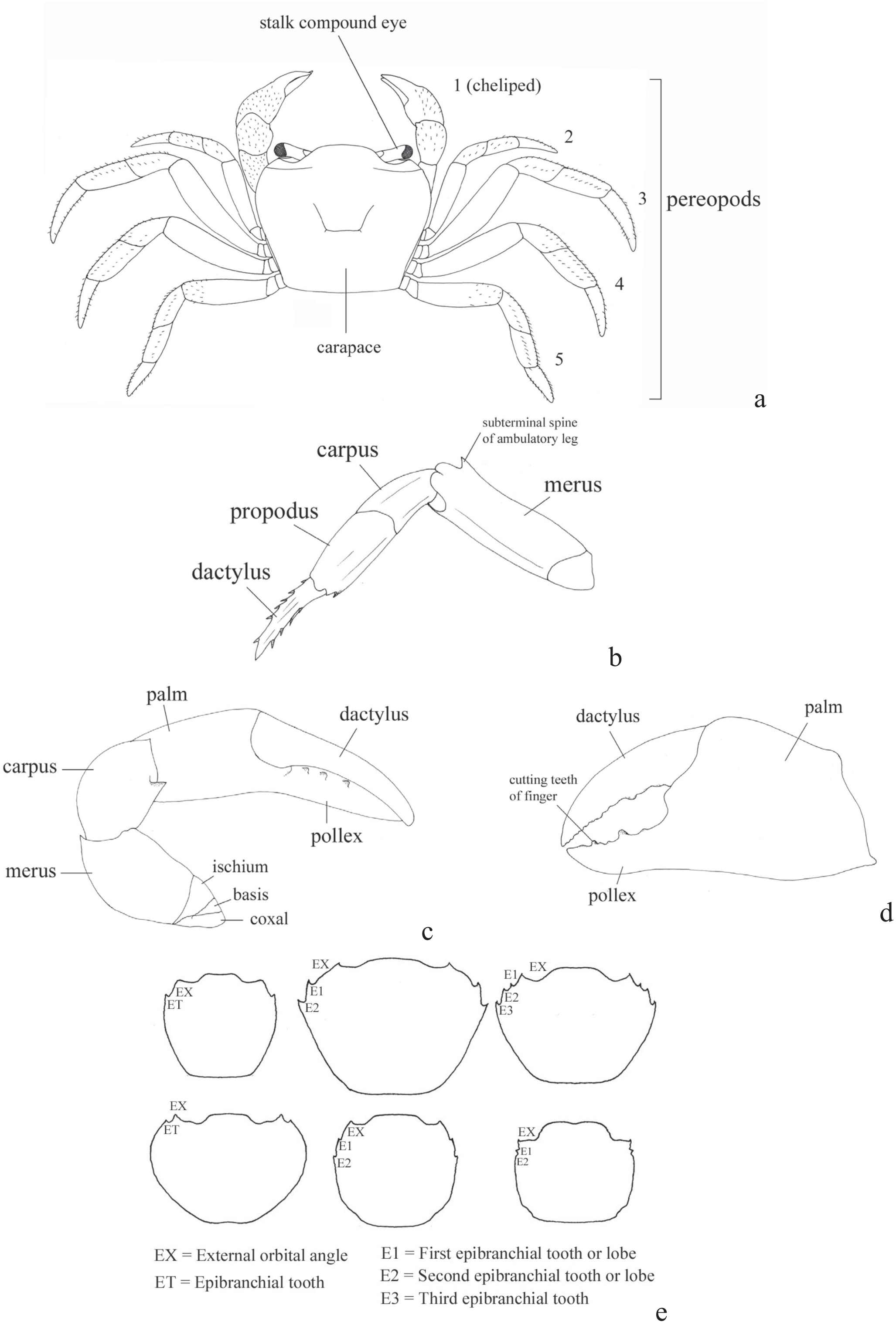


Fig. 2 a. Dorsal view of a Potamid crab; b. Walking leg; c. Left cheliped; d. Chela; e. Carapace shapes of various freshwater crabs (redrawn from Ng, 1988, fig. 5).

KEY TO CLASSES AND ORDERS OF FRESHWATER CRUSTACEA

1 Cephalothorax with 8 segments, abdomen with 6 segments; usually with uropods (except crabs) (Fig. 1,13,14)..CLASS MALACOSTRACA...11
1′ Body divided into head and trunk; if cephalothorax present, abdomen with 3-5 segments;abdomen without uropods 2

2(1′) Trunk with more than 10 segments and with leaf-like appendages (Fig. 8,9,10)....... ....CLASS BRACHIOPODA...8
2′ Appendages not leaf-like 3

3(2′) External parasites of fishes 4
3′ Animals free living 5

4(3) Body flattened and disc-like with a pair of ventral surface circular sucker (Fig. 3) .. .. CLASS BRACHIURA
4′ Body various formed; if body flattened, not disc-like and without sucker................ ....CLASS COPEPODA (part parasitic form)

5(3′) Head indistinctly set off from trunk and covered with bivalve carapace; thorax with only two pairs of appendages (Fig. 4) ....CLASS OSTRACODA
5′ Body long, cylindrical or pear-shaped, with cephalothorax, thorax and abdomen; thorax with 4-6 pairs of appendages; cephalothorax with a nauplius eye ....CLASS COPEPODA.....8

6(5′) Cephalothorax not distinctly broader than abdomen, body pear-shaped, up to 3 mm long (Fig. 6,7) 7
6′ Cephalothorax broader than abdomen, body more or less cylindrical; less than 1 mm long (Fig. 5)... ORDER HARPACTICOIDA

7(6′) The first antenna very long, usually longer than whole body; egg sacs single (Fig. 6) .... ORDER CALANOIDA
7′ The first antenna moderate; egg sacs paired (Fig. 7)....................ORDER CYCLOPOIDA

8(2) Carapace present; eyes sessile 9
8′ Carapace absent; eyes stalked (Fig. 8).. ORDER ANOSTRACA

9(8) Telson with two long filamentous cerci; univalve carapace covers head and some of trunk; tadpole-like (Fig. 9)... ORDER NOTOSTRACA
9′ Telson without filamentous cerci; abdomen covered by carapace......................... 10

10(9′) Carapace a single folded plate, covering thorax and abdomen but not covering head; 4-6 pairs of thoracic appendages (Fig. 10)......................... ORDER CLADOCERA

10′ Carapace bivalve, covering thorax and trunk; 11-28 pairs of thoracic appendages (Fig. 11) .... ORDER CONCHOSTRACA

11(1) Carapace absent; eyes sessile 12

11′ Carapace present; eyes stalked 13

12(11) Body laterally flattened (Fig. 12) ....ORDER AMPHIPODA

12′ Body dorsoventrally compressed (Fig. 13)....................................... ORDER ISOPODA

13(11′) Thoracic appendages not chelate... ORDER MYSIDACEA

13′ Five pairs of walking legs of which at least the first pair is chelate (Fig. 14,15a) ....ORDER DECAPODA.....14

14(13′) Abdomen reduced and folded beneath the cephalothorax; swimming legs not developed (Fig. 14).. INFRAORDER BRACHYURA (crabs)

14′ Abdomen and swimming legs well developed; carapace with conspicuous rostrum; body more or less laterally compressed.............................INFRAORDER CARIDEA....15

15(14') First two pairs of thoracic legs slender, without apical tufts of setae; (Fig. 15a-b) small to largeSize; in streams and rivers .... PALAEMONIDAE, *Macrobrachium*

15' First two pairs of thoracic legs broad, with apical tufts of setae (Fig. 16a-b); very small size, length less than 35 mm; in small stony streams .... ATYIDAE, *Caridina*

KEY TO FAMILIES OF FRESHWATER CRABS OF INDOCHINA

1 Mandibular palp with two lobes (Fig. 17); frontal margin of carapace usually with a distinctly or indistinctly marked median triangle (Fig. 20,21); abdomen of male T-shape (Fig. 23)...SUPERFAMILY GECARCINUCOIDEA ...2

1′ Mandibular palp with three lobes (Fig. 18); frontal margin of carapace entire (Fig. 19); abdomen of male triangular shape (Fig. 22)... ....SUPERFAMILY POTAMOIDEA (POTAMIDAE)

2(1) Anterolateral margin with one tooth (Fig. 24) frontal median triangle indistinctly marked (Fig. 20); exopod of the third maxilliped with very short or without flagellum (Fig. 25) .... GECARCINUCIDAE

2′ Anterolateral margin with one or more teeth (Fig. 26); frontal median triangle distinctly demarcated (Fig. 21); exopod of the third maxilliped with long flagellum (Fig. 27) .... PARATHELPHUSIDAE

KEY TO SPECIES OF FRESHWATER PRAWNS OF THE GENUS *MACROBRACHIUM* OF INDOCHINA

1 Carpus of the second pereopod covered with dense velvety pubescence (Fig. 28,29,31) 2
1′ The second pereopod without dense velvety pubescence (Fig. 34) 6

2(1) Pubescence occurs on both palm and finger 3
2′ Pubescence occurs only on proximal half or third of fingers (Fig. 28) (cutting edge of fixed finger not razor-like) .... *M. sintangense*

3(2) Carpus cup-shaped; less than twice as long as high, cutting edges of fingers of second pereopod with less than 18 teeth 4
3′ Carpus elongate, more than twice as long as high, cutting edges of fingers of second pereopod with more than 20 teeth (Fig. 29) .... *M. dienbienphuense*

4(3) Propodus of third pereopod more than three times as long as dactylus (epistome trilobed, cutting edges of fingers of second pereopod with 12-15 teeth (Fig. 30) .... *M. eriocheirum*
4′ Propodus of third pereopod less than three times as long as dactylus 5

5(4′) Epistome trilobed, second pereopod of both sexs are similar in size .... *M. amplimanus*
5′ Epistome bilobed, second pereopod of female much smaller than that of male (Fig. 31) .... *M. hirsutimanus*

6(1′) Carpus of second pereopod longer than chela (Fig. 32), (rostum upturned, reaching distinctly beyond end of scaphocerite, second pereopods shorter than body, anterior of rostum unteethed) .... *M. lanchesteri*
6′ Carpus as long as or shorter than chela 7

7(6′) Carpus of the second pereopod longer than palm but shorter than chela (Fig. 33) (rostum upturned with more than 10 ventral teeth, fingers of second pereopods with teeth on cutting edges) .... *M. rosenbergii*
7′ Carpus of the second pereopod shorter than palm 8

8(7′) Second pereopods equal in length, movable spines on uropodal diaeresis shorter than outer angle 9
8′ Second pereopods subequal in length, movable spines on uropodal diaeresis longer than outer angle (Fig. 34) (fingers of second pereopod with one row of 10-20 small teeth on cutting edges) .... *M. thai*

9(8) Rostrum not reaching beyond end of antennular peduncle (Fig. 35), antennular peduncle 0.4 times as long as carapace .... *M. yui*

9′ Rostrum reaching beyond end of antennular peduncle (Fig. 36), antennular peduncle 0.5 times as long as carapace .... *M. mieni*

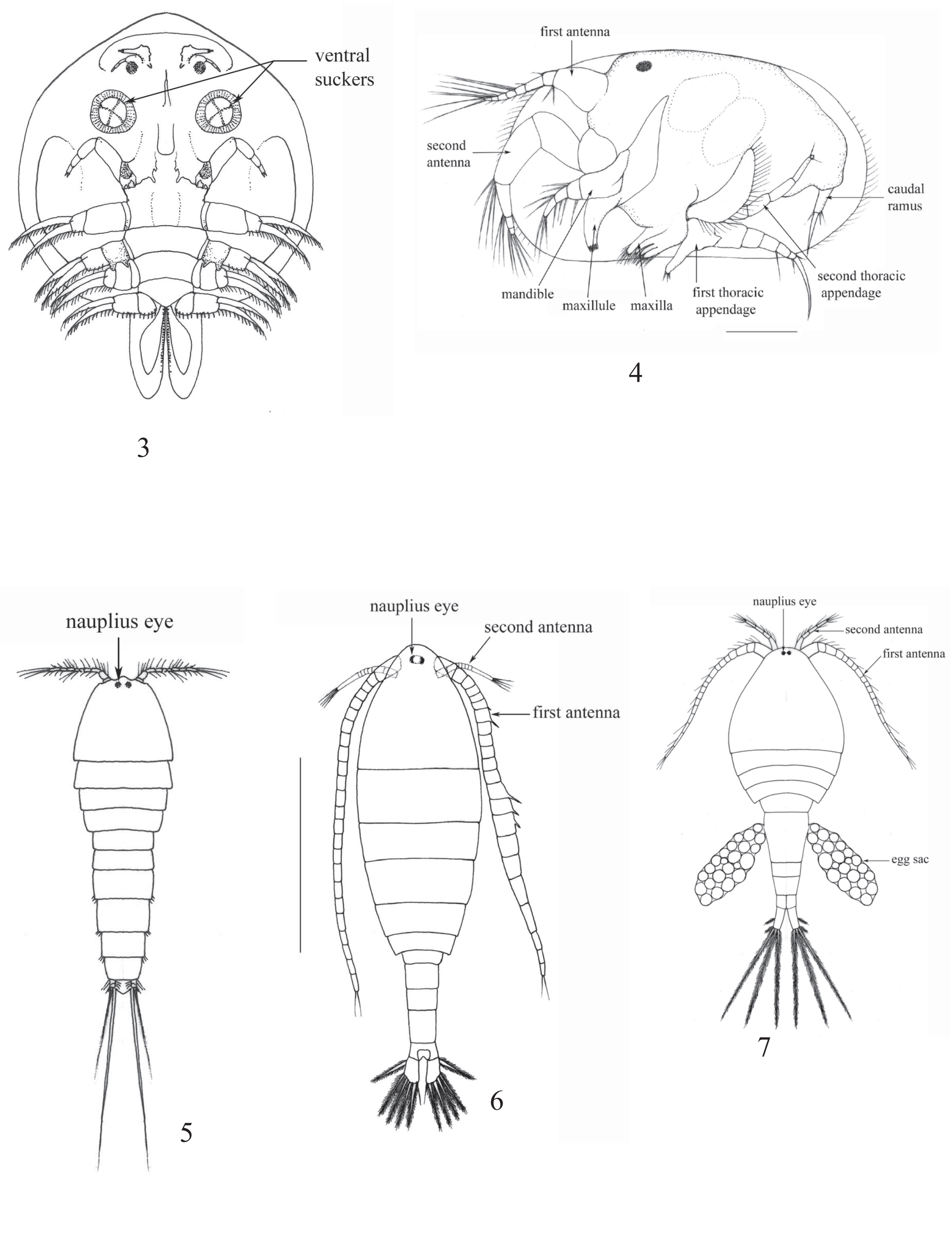


Fig. 3-7 3. Ventral view of Argulidae (redrawn from Pennak, 1989, fig. 9); 4. Side view of an ostracod; 5. Dorsal view of harpacticoid copepod (modified from Pennak, 1989, fig. 3A); 6. Dorsal view of calanoid copepod; 7. Dorsal view of cyclopoid copepod.

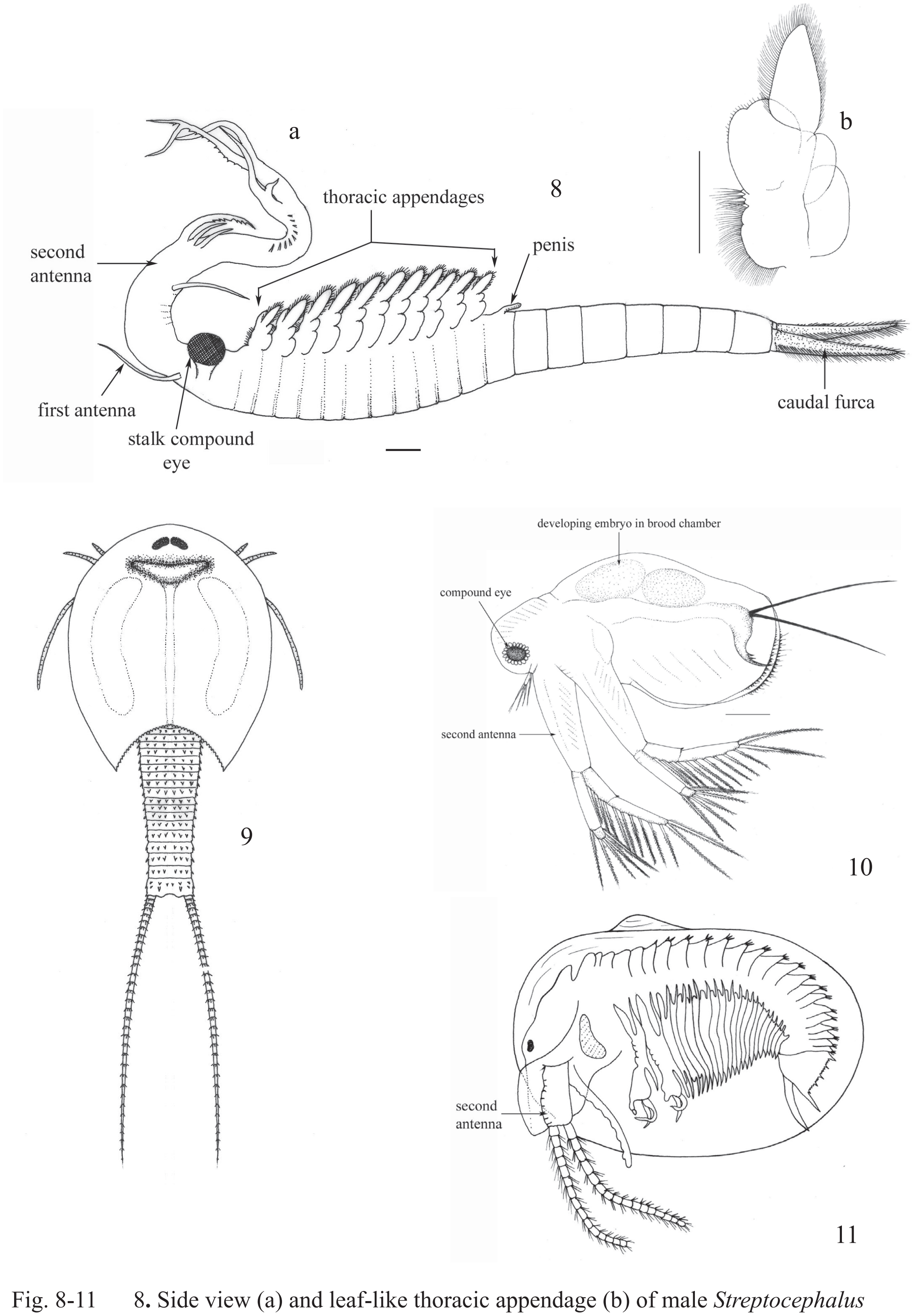


Fig. 8-11 8**.** Side view (a) and leaf-like thoracic appendage (b) of male *Streptocephalus sirindhornae*; 9. Dorsal view of tadpole shrimp (modified from Pennak, 1989, fig. 3D); 10. Side view of cladoceran; 11. Side view of conchostacan (redrawn from Barnes, 1963, fig. 15-9A).
Scale = 1 mm.

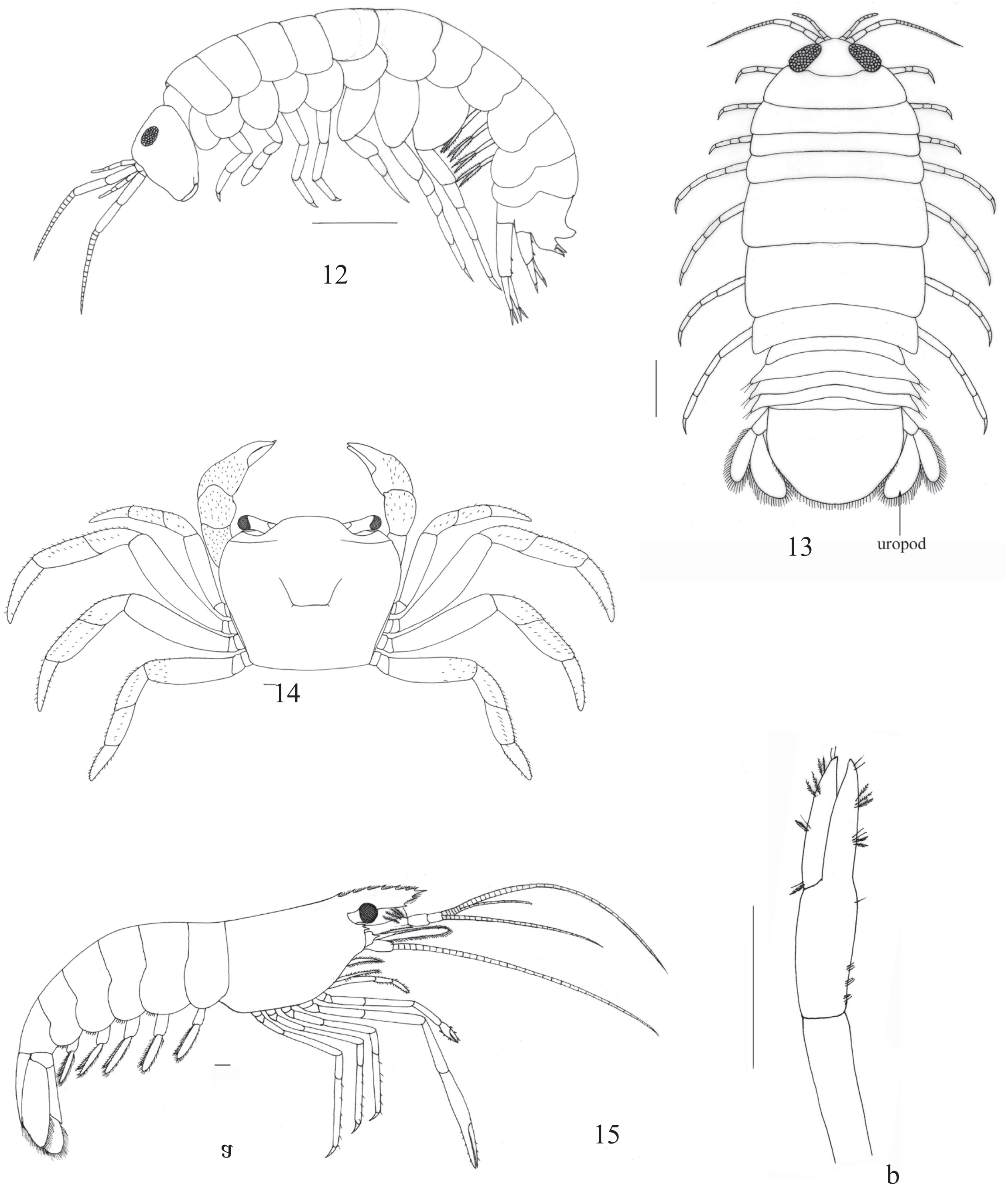


Fig. 12-15 12. Side view of amphipod; 13. Dorsal view of isopod; 14. Dorsal view of potamid crab; 15. Side view (a) and thoracic leg (b) of *Macrobrachium* sp. Scale: (12,13,14,15a) 1 mm; (15b) 0.5mm.

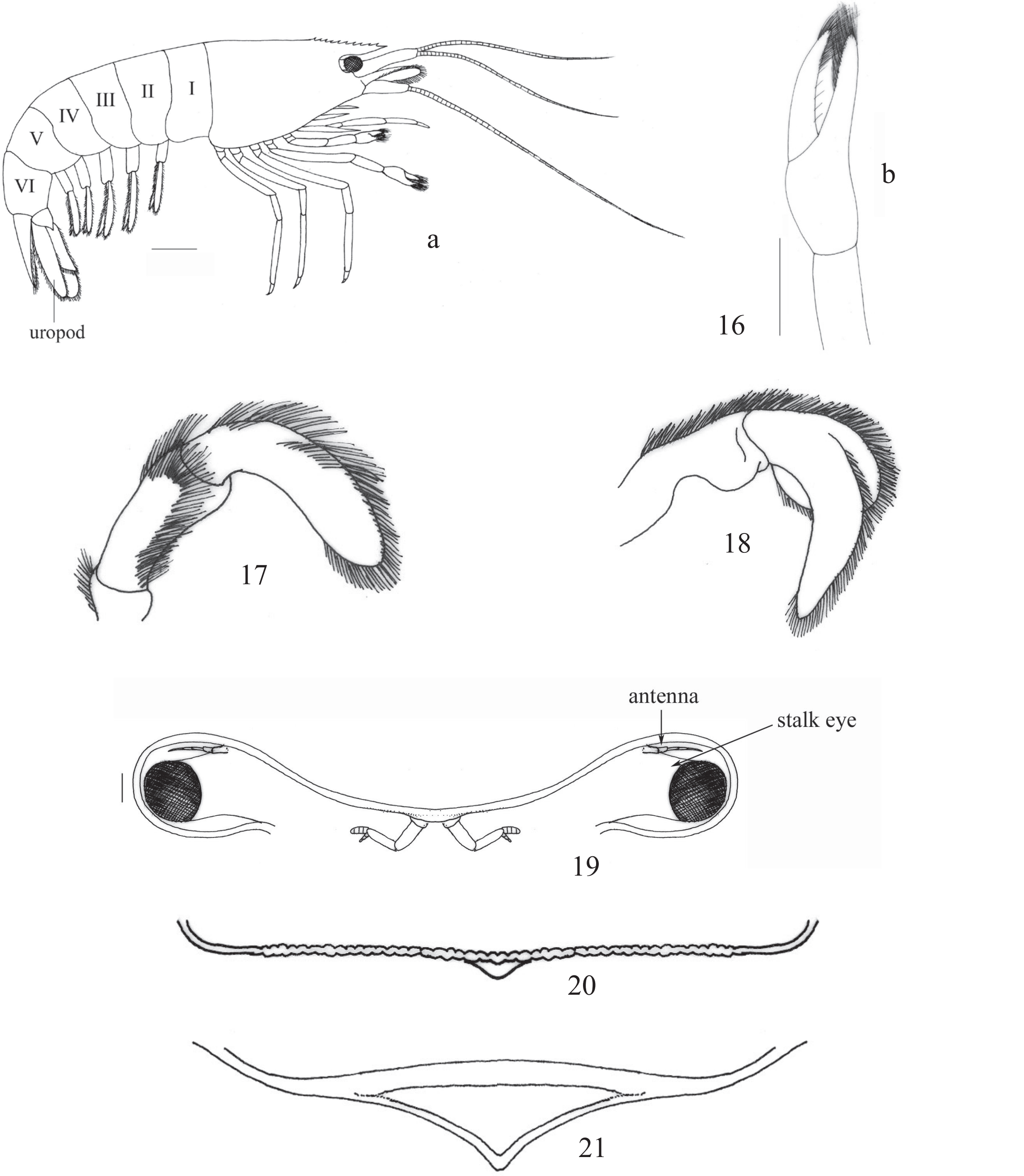


Fig. 16-21 16. Side view (a) and thoracic leg (b) of *Caridina* sp.; 17. Mandibular palps of Potamoidea (redrawn from Ng, 1988, fig. 2A); 18. Mandibular palps of Gecarcinucoidea (redrawn from Ng, 1988, fig. 2B); 19. Frontal margin of potamid crab; 20. Frontal median triangles of Gecarcinucidae (redrawn form Ng, 1988, fig. 38A); 21. Frontal median triangles of Parathelphusidae (redrawn form Ng, 1988, fig. 38B).(redrawn from Ng, 1988, fig. 11A).
Scale = 1 mm.

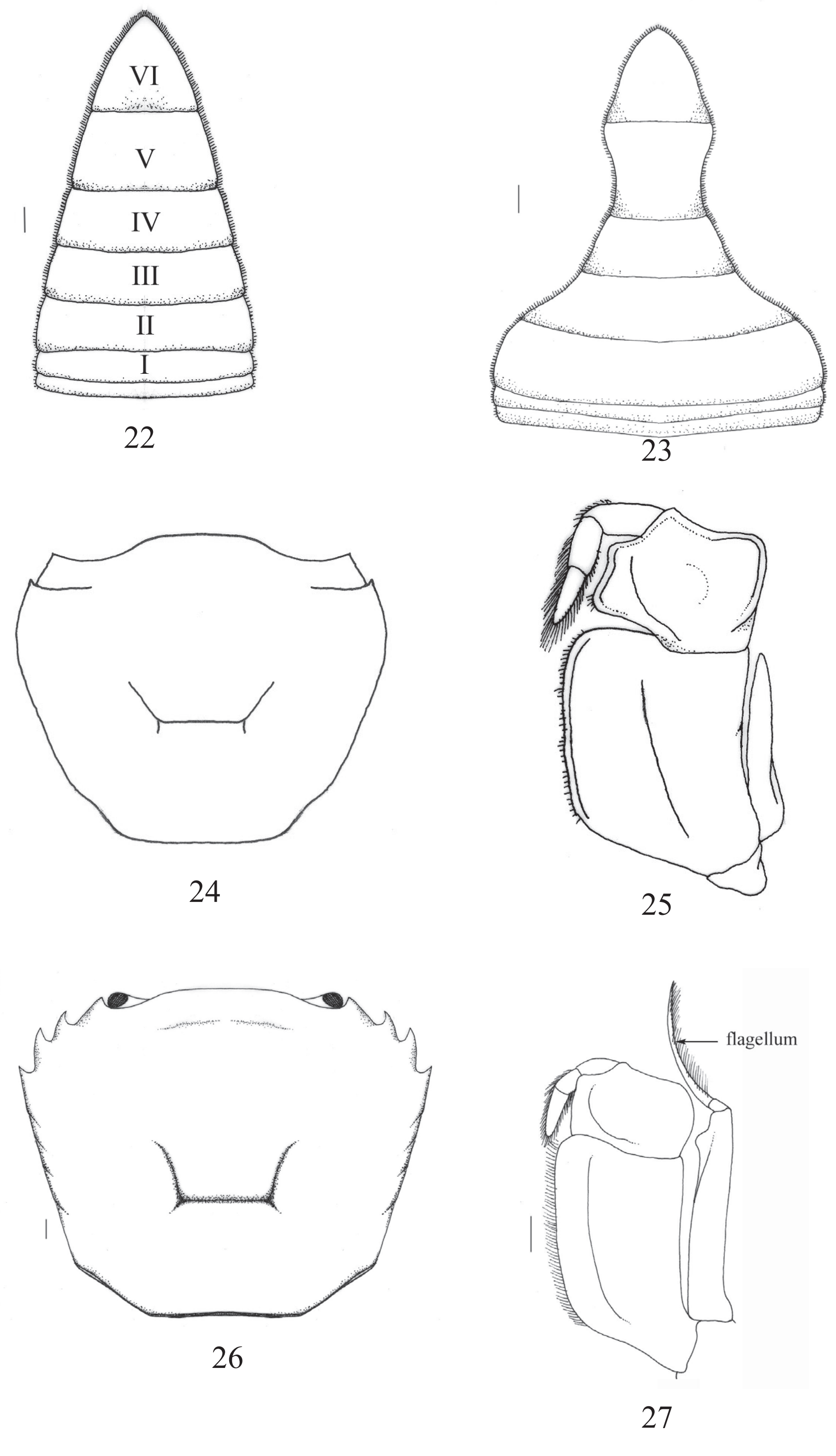


Fig. 22-27 22. Dorsal view of abdomen of Potamidae; 23. Dorsal view of abdomen of Parathelphusidae; 24. Dorsal view of carapace of Gecarcinucidae (modified from Ng, 1988, fig. 18A); 25. Left third maxilliped of Gecarcinucidae (redrawn from Ng, 1988, fig. 40C); 26. Dorsal view of carapace of Parathelphusidae; 27. Left third maxilliped of Parathelphusidae.
Scale = 1 mm.

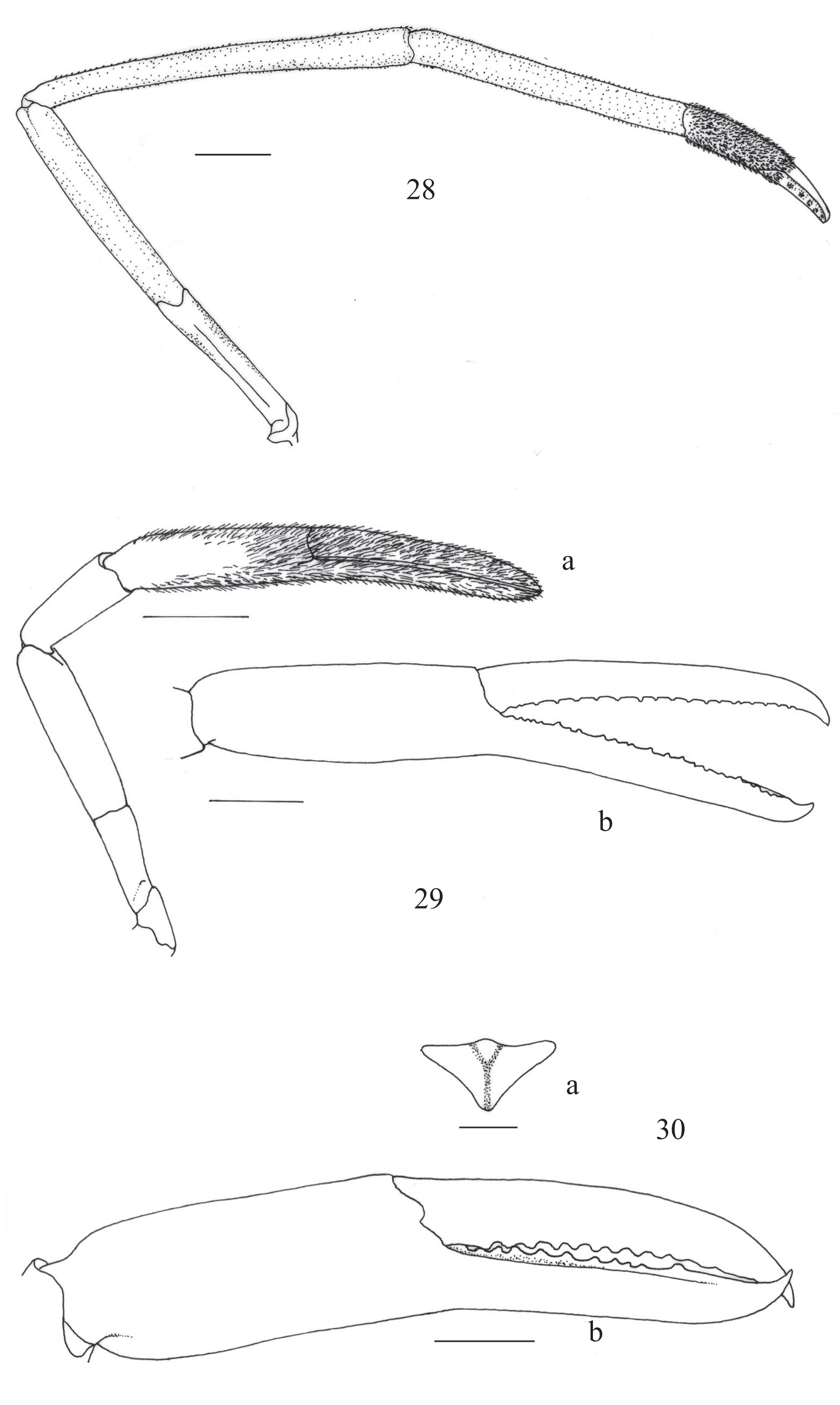


Fig. 28-30 28. Second pereopod of *Macrobrachium sintangense* (redrawn from Cai *et al*., 2004, fig. 2H); 29. Second pereopod (a) and chela of second pereopod (b) of *M. dienbienphuense* (redrawn from Cai *et al*., 2004, fig. 20J,K); 30. Epistome (a) and chela of second pereopod (b) of *M. eriocheirum* (redrawn from Cai *et al*., 2004, fig. 18B, D).
Scale: (28,29,30b) 5 mm; (30a) 2 mm.

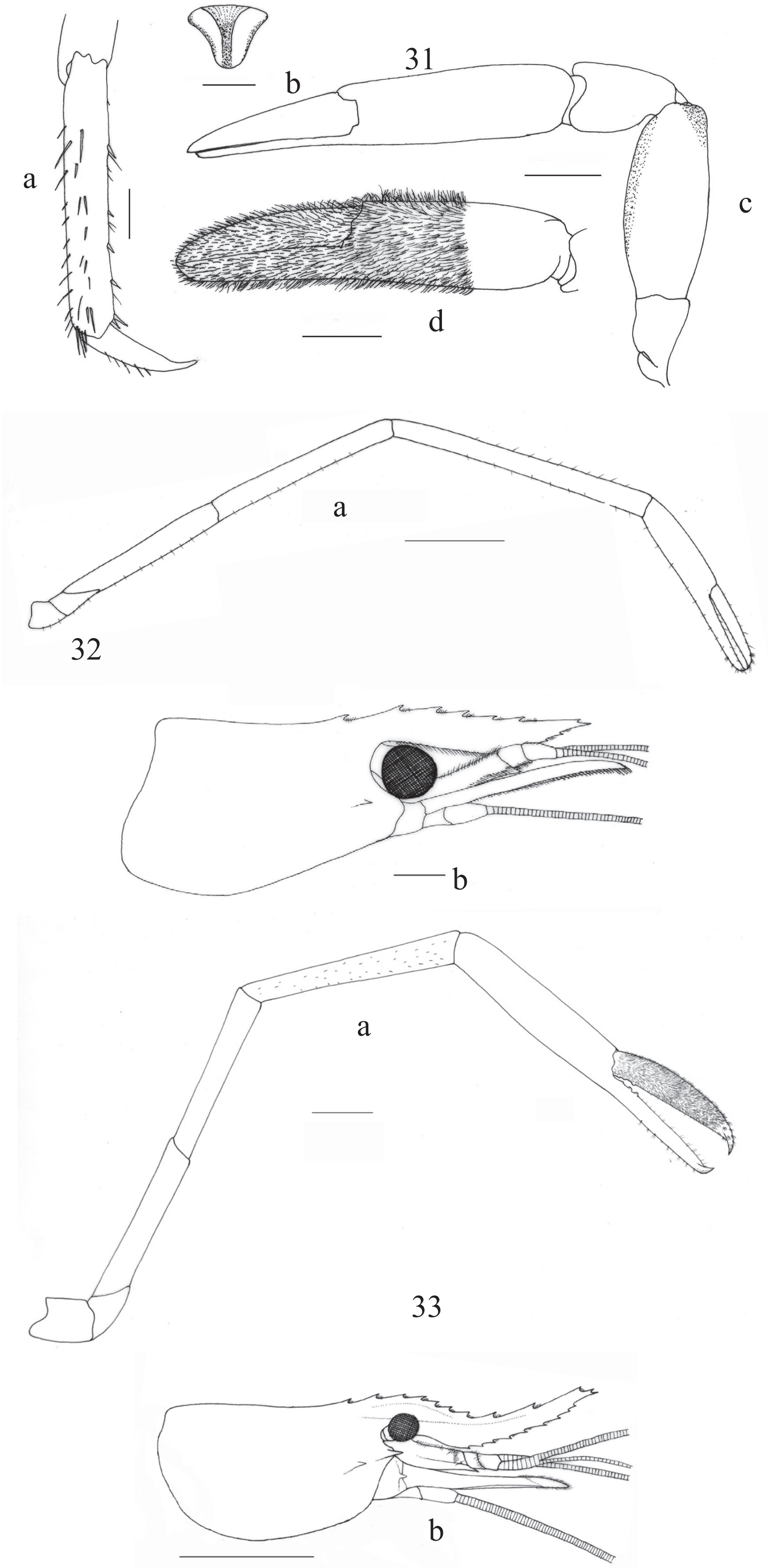
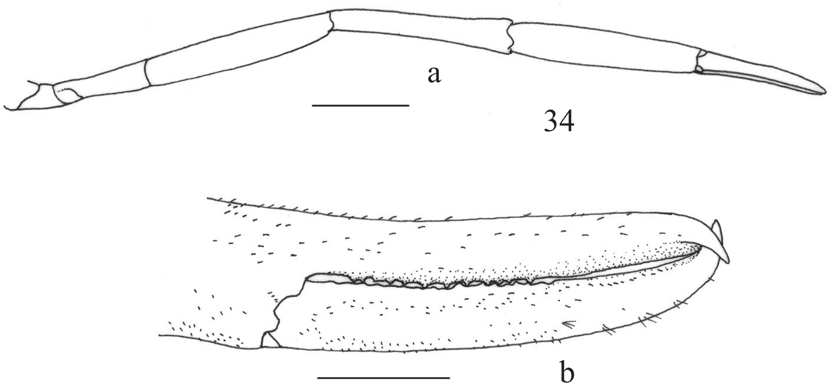
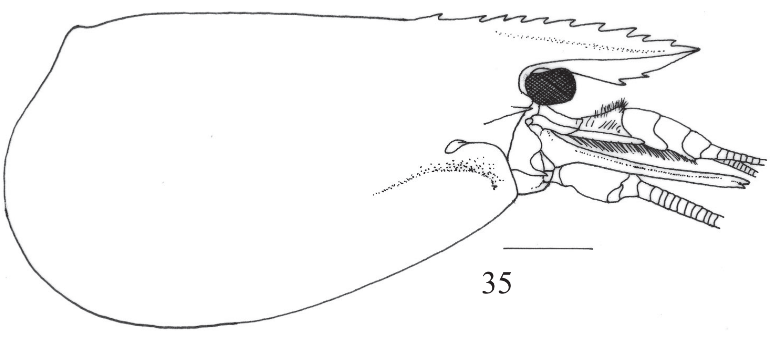


Fig. 31-33 31. Second pereopod (a), epistome (b), chela of second pereopod (c) and prododus and dactylus (d) of *M. hirsutimanus* (redrawn from Cai *et al*., 2004, fig. 15B,G,H,K); 32. Second pereopod (a) and side view of cephalothorax (b) of *M. lanchesteri*; 33. Second pereopod (a) and side view of cephalothorax (b) of *M. rosenbergii*.
Scale: (31b,c) 5 mm; (31a, 31d, 32-33) 1 mm.





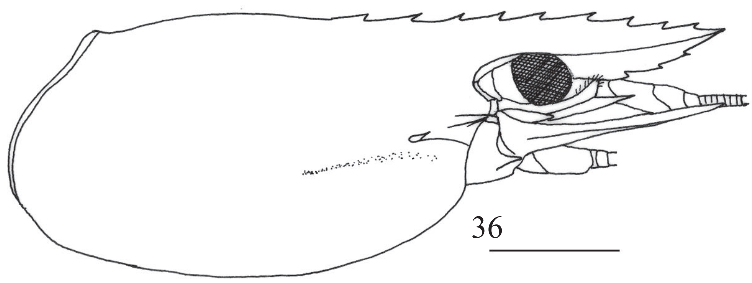


Fig. 34-36 34. Second pereopod (a) and finger of second pereopod (b) of *M. thai* (redrawn from Cai *et al*., 2004, fig. 9H,I) 35. Side view of cephalothorax of *M. yui* (redrawn from Cai *et al*., 2004, fig. 10A); 36. Side view of cephalothorax of *M. mieni* (redrawn from Cai *et al*., 2004, fig. 11A).
Scale line: (34) 2 mm; (35-36) 5 mm

Chapter 13 The Aquatic and Semiaquatic Insect Orders

Collembola includes ametabolous insects that show many embryological features in common with the myriapods. While Collembola is no longer considered to be a member of the class Insecta it has always been included in Entomology textbooks. In the present study, we treat collembolans as semiaquatic insects.

There are 13 Orders of aquatic and semiaquatic insects. Excepting Collembola, the others can be divided into two groups based on individual development. **Hemimetabolous** insects are groups of insects in which the external form of the immature stages (nymphs) gradually approaches, through a series of instars, the form of the adults. They are also called **exopterygotes** because wing buds develop externally and are clearly visible throughout the nymphal stages. The last nymphal stage resembles the adult very closely but is not sexually mature. Hemimetabolous insects include five orders: Ephemeroptera, Odonata, Plecoptera, Orthoptera and Hemiptera. The other group is the **holometabolous** insects, in which the immature stages (or larvae) do not resemble the adults. Metamorphosis is complete from egg to larval, pupal and adult stages. In the pupal stage there is a marked change in external appearance. The development of wing buds takes place internally, so they are called **endopterygotes**. There are seven orders: Megaloptera, Neuroptera, Coleoptera, Diptera, Lepidoptera, Trichoptera and Hymenoptera.

Among the 13 aquatic and semiaquatic insect orders, stoneflies (order Plecoptera) exibit basic morphological features of insects. So, they are ideal for illustrating the general external morphology of insects.

The body is divided into three major tagmata: **head**, **thorax** and **abdomen**. The head is the centre of sensation and ingestion. The sensory organs are the compound eyes, ocelli (simple eyes) and antenna (Fig. 1a). The basic chewing mouthparts consist of labrum (the upper lip), mandible, maxilla and labium (the lower lip) as shown in Fig. 2.

The thorax has three segments: prothorax, mesothorax and metathorax. It is the centre of locomotion. Each segment bears a pair of jointed legs. In Exopterygota, there are pair of developing wing pads on the meso-and metathoracic segments respectively. Larvae of Diptera lack jointed legs but may have one or more fleshy prolegs (Fig. 16). The jointed legs have five segments, including coxa, trochanter, femur, tibia, 1-5 subsegments of the tarsus and one or two claws at the end of the tarsus (Fig. 3). Gills may be present on the thoracic segments.

The abdomen is the centre of digestion, circulation and respiratiom. Stoneflies have ten abdominal segments, but some insects may have eight or nine segments. The abdomen of immature insects may bear various paired lateral appendages such as gills, prolegs and various projections. The last abdominal segment bears an anus. Mature nymphs of Ephemeroptera, Hemiptera, Odonata and Plecoptera bear the developing reproductive structures and a pair of cerci (Fig. 1b) at the end of the abdomen. These structures may be visible as a mid-dorsal supra-anal process and epiprocts and a pair of ventral paraprocts.

In Coleoptera and Hemiptera both immature and adult stages are aquatic, but in the other orders only the immatures are aquatic. Thus, keys for both the immature and adult stages of Hemiptera and Coleoptera have been constructed, whereas for the other 11 orders there are only keys to immature stages.

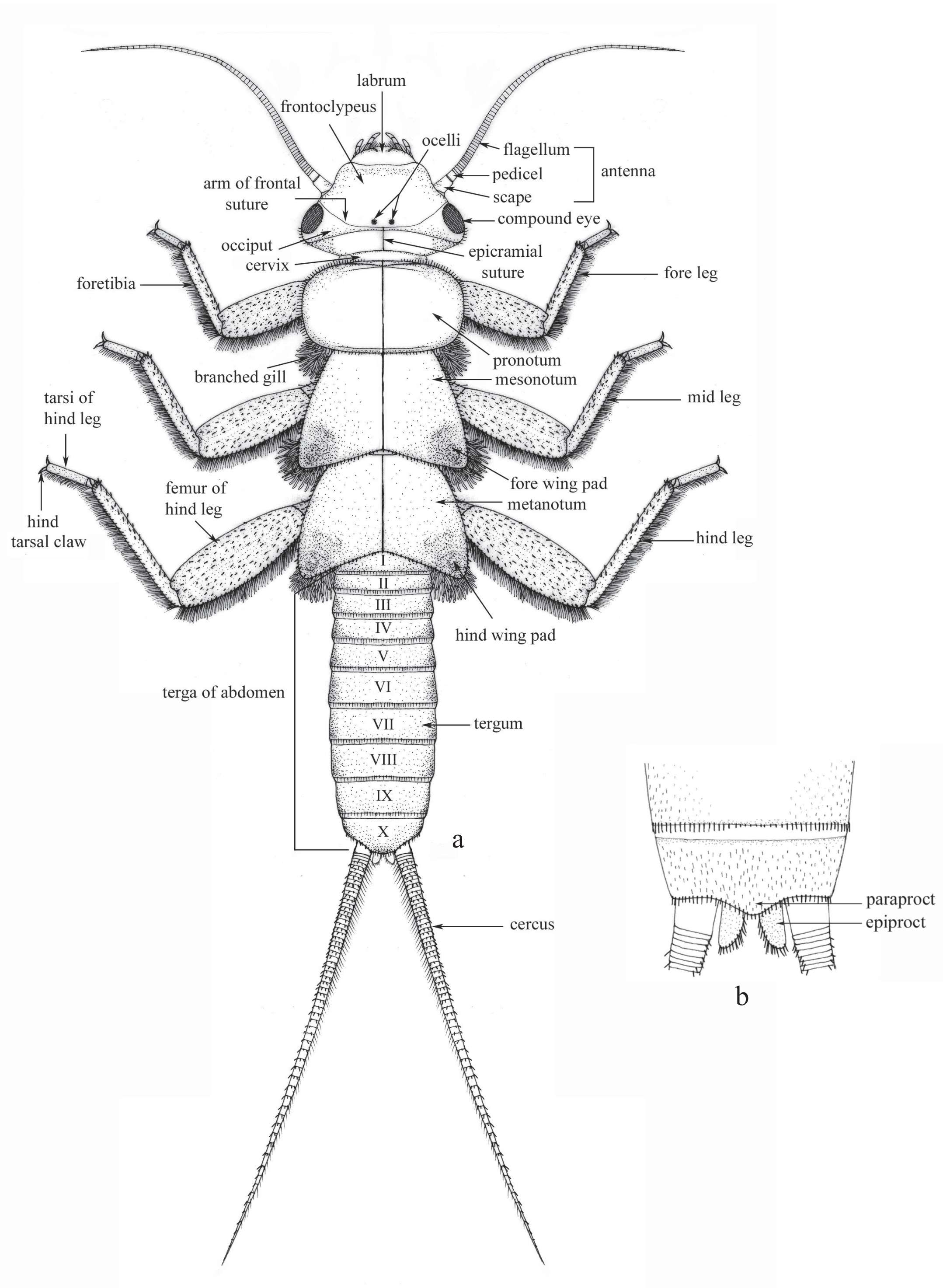
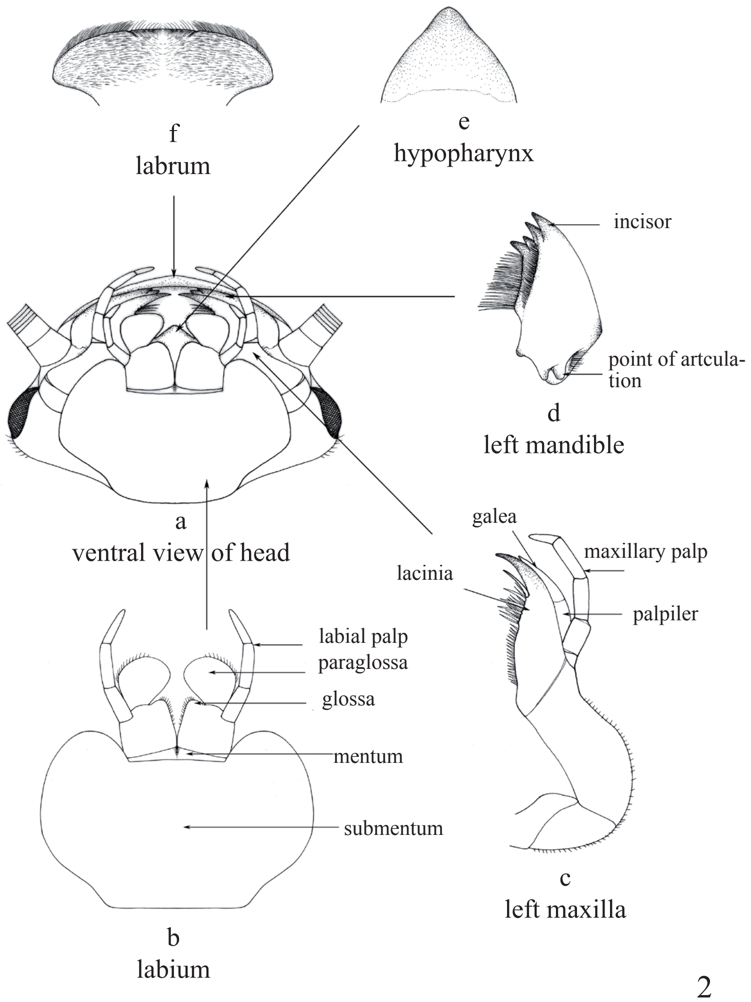


Fig. 1 Dorsal view (a) and ventral view of posterior end (b) of *Etrocorema nigrogeniculatum* nymph (Plecoptera, Perlidae).



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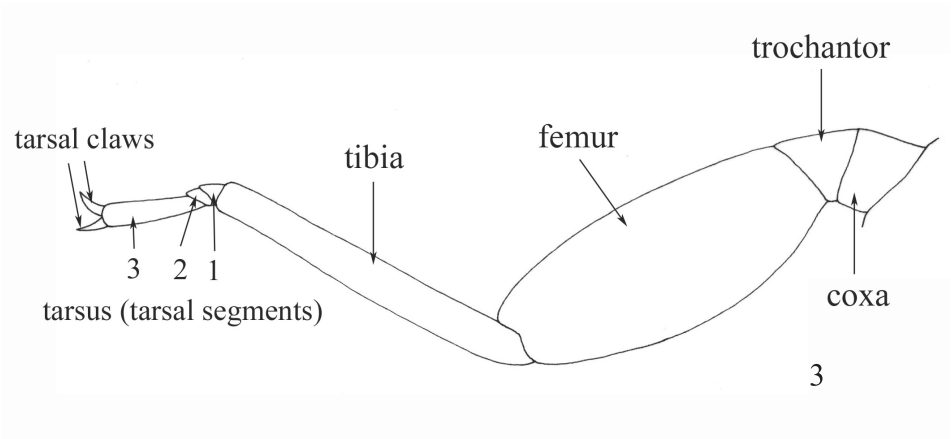


Fig. 2-3 2. Ventral view of head and mouthparts of *Etrocorema nigrogeniculatum*. nymph: a, ventral view of head; b, labium; c, left maxilla; d, left mandible; e, hypopharynx; f, labrum; 3. Hind leg of *Etrocorema nigrogeniculatum* nymph showing segments

Key to Aquatic Insects and Semiaquatic Orders of Indochina

1 Body is in cocoon or body mummy-like; legs, wings and antennae fused or pressed against the body wall (Fig. 4) .... pupa
1′ Body is not in ocoon .... larvae…2

2(1′) Small insects, usually 1-2 mm; 4-6 abdominal segments, with forked spring apparatus under abdomen (Fig. 5) .... Collembola (springtails) (p. 101)
2′ Large insects (usually); never with the forked spring-like apparatus 3

3(2′) Head with piercing mouth-parts (Fig. 6) .... Hemiptera (bugs) (p. 147)
3′ Head with chewing mouthparts (Fig. 2) 4

4(3′) Wing buds present on thoracic segments (Fig. 9) 5
4′ Wing buds absent.. 8

5(4) Femur of hind legs enlarged and modified for jumping (Fig. 7a) (except Blaberidae (Fig. 7b); shore insects.........Orthoptera (p. 135) (mole crickets and grass hoppers)
5′ Hind legs normal shape and size; true aquatic insects.. 6

6(5′) Elbowed mask-like labium covering mouth ....(Fig. 8) Odonata (p. 125) (damselflies and dragonflies)
6′ Mouth not covered by a mask-like labium 7

7(6′) Legs with a single tarsal claw, usually with 3 terminal filaments (Fig. 9) (rarely 2 filaments) ....Ephemeroptera (p. 103) (mayflies)
7′ Legs with two tarsal claws, 2 terminal filaments (Fig. 10).. .... Plecoptera (stoneflies) (p. 137)

8(4′) Thoracic segments with 3 pairs of segmented legs (Fig. 11,12,13,14).................... 9
8′ Segmented legs absent on thoracic segments (Fig. 16) 12

9(8) Fleshy legs with tiny hooks (crotchets) on the abdomen (Fig. 11)............................ .... Lepidoptera (p. 213)
9′ Without fleshy hook-bearing legs present on the abdomen.................................. 10

10(9′) With 7-8 pairs of lateral abdominal gills; end of abdomen with 4 claws or a single terminal filament (Fig. 12)............................ Megaloptra and Neuroptera (p. 179)
10′ Without gills or with dorsal or ventral abdominal gills; end of abdomen without claws or with 2 claws.. 11

11(10′) End of abdomen with a pair of lateral hooked claws and prolegs (Fig. 13a); antenna 1 segment and usually very short (Fig. 13b) ....TRICHOPTERA (caddisflies) (p. 181)

11′ End of abdomen usually without hooked claws (Fig. 14a); antenna with more than 1 segment (Fig. 14b) ....COLEOPTERA (beetles) (p. 217)

12(8′) Larva headless, legless, body less than 2 mm; pupa up to 5 mm (Fig. 15a); both larva and pupa living as parasites inside insect eggs or insect bodies; producing a long ribbon that extend outside the case of host (Fig. 15b)....................................... .... HYMENOPTERA (parasitic wasps) (p. 229)

12′ Head and body vary (Fig. 16); free living .... DIPTERA (true flies) (p. 231)

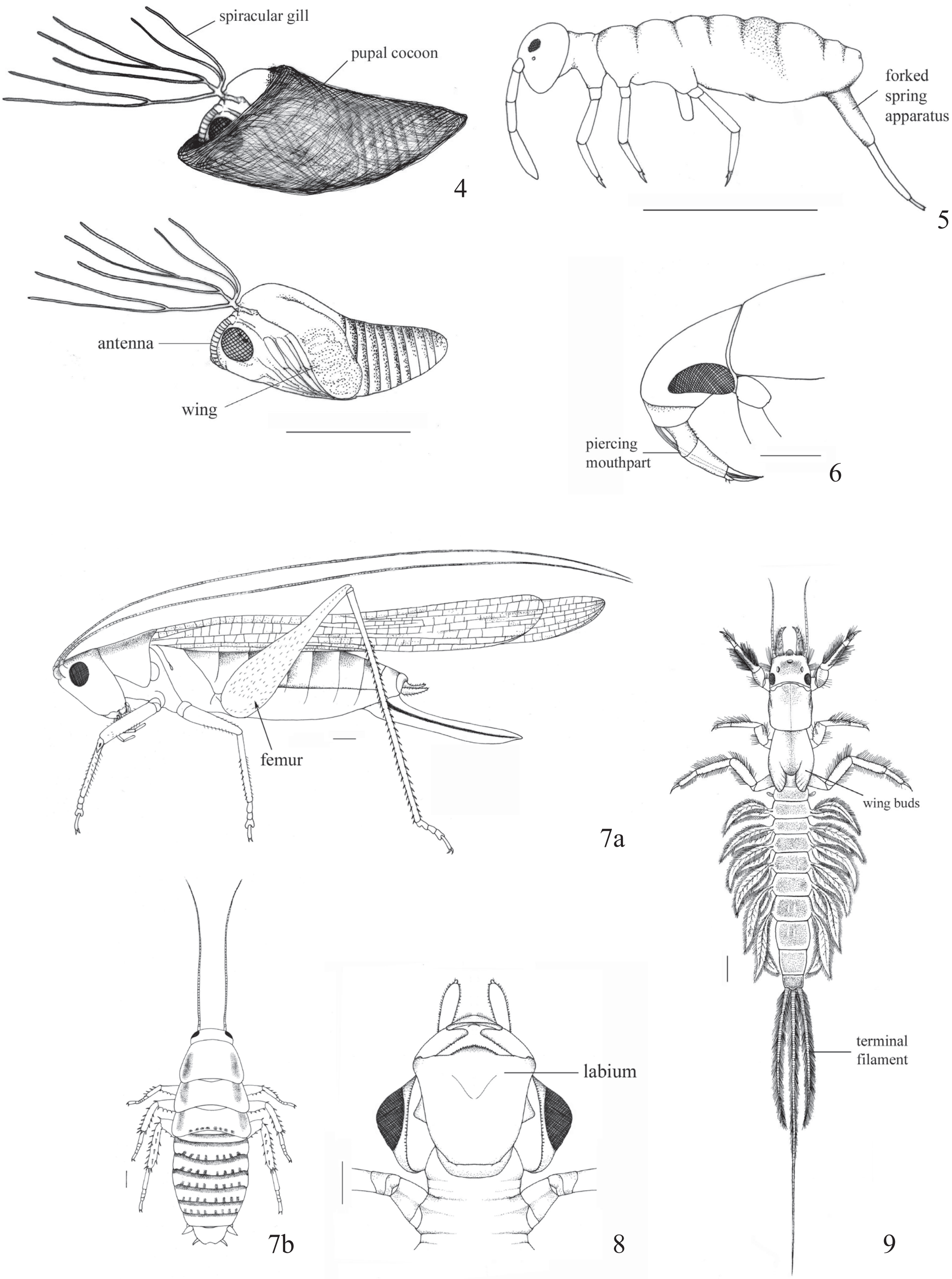


Fig. 4-9 4. Pupa of Simuliidae (Diptera); 5. Side view of springtail (Collembola); 6. Side view of head of Belostomatidae (Hemiptera);7. Lateral view of female katydids (a) and dorsal view of Blaberidae (b) (Orthoptera); 8. Ventral view of head of Gomphidae (Odonata); 9. Dorsal view of nymph of Polymitarcyidae (Ephemeroptera).
Scale: (4,6,7,8,9) 1 mm; (5) 0.5 mm

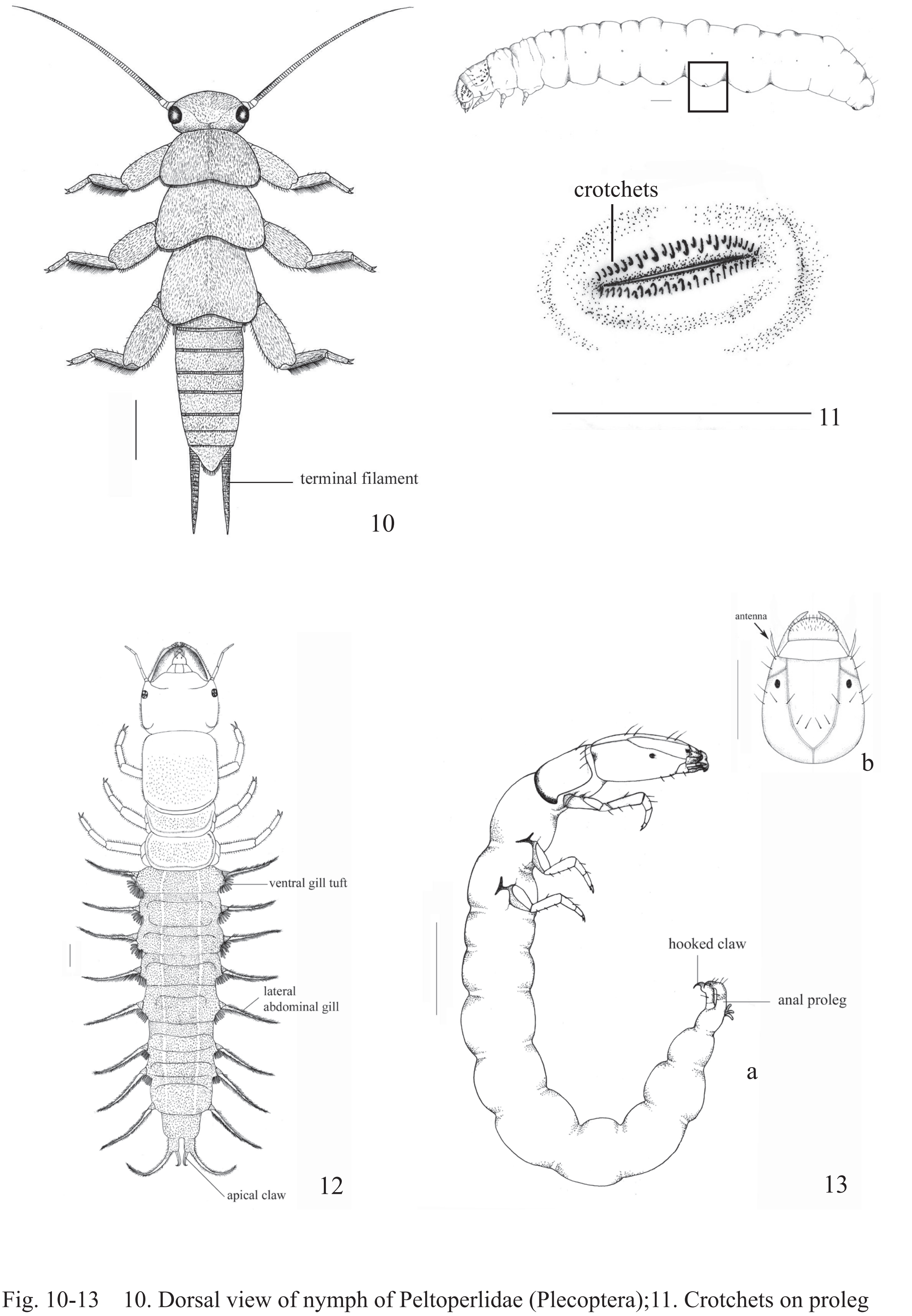


Fig. 10-13 10. Dorsal view of nymph of Peltoperlidae (Plecoptera);11. Crotchets on proleg of *Elophila* sp. (Lepidoptera); 12. Dorsal view of larva of *Protohermes* sp. (Megaloptera); 13. Side view of Philopotamidae larva (a) and dorsal view of head of Leptoceridae larva (b) (Trichoptera).
Scale: (10,12,13) 1 mm; (11) 0.5 mm.

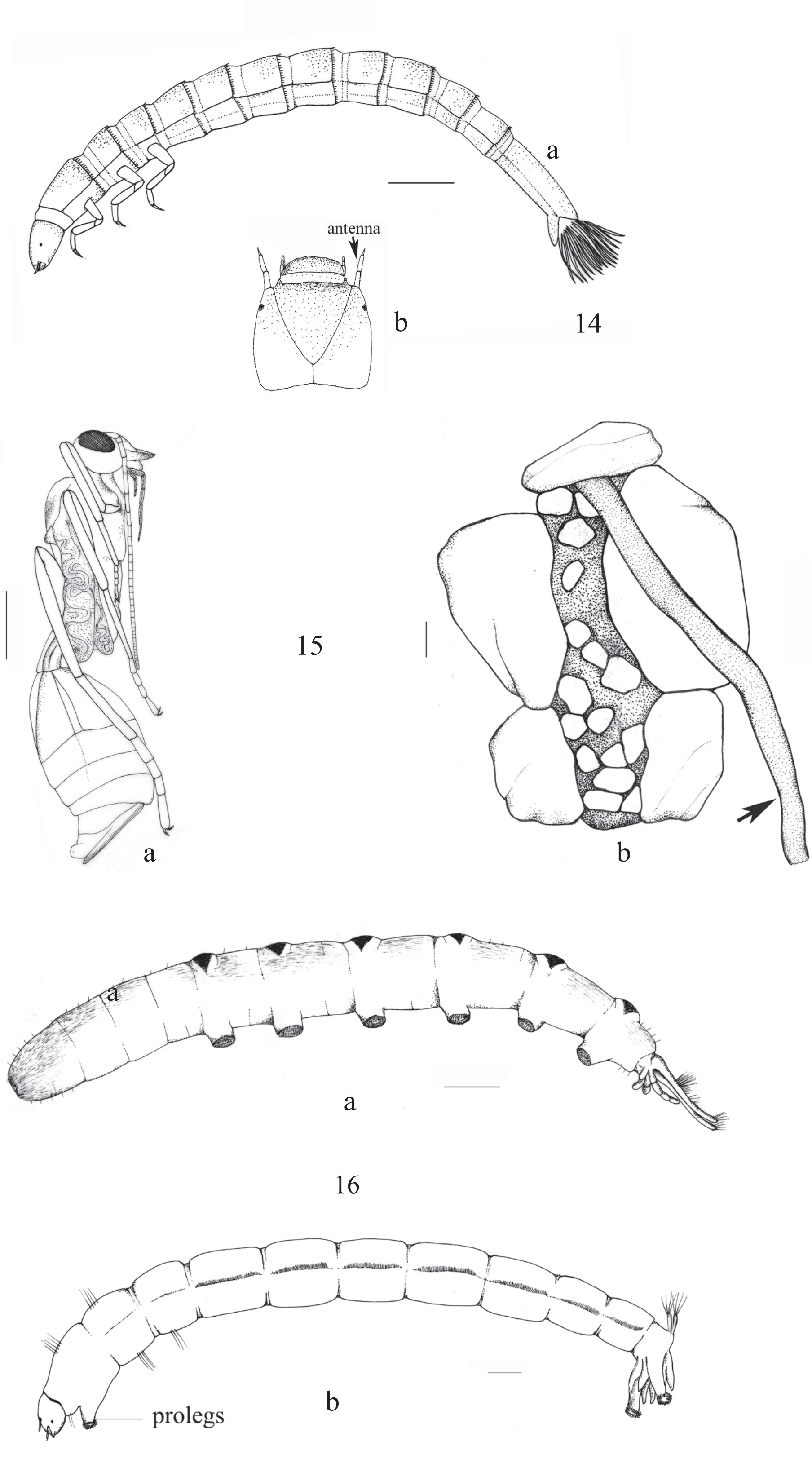


Fig. 14-15 14. Side view of larva (a) and dorsal view of head (b) of Elmidae (Coleoptera); 15 Pupa (a) of aquatic parasitoid (Hymenoptera), that has been removed from the pupalcase (b) of Goerid caddisfly and respiratory ribbon produced by the parasitoid; 16. Lateral view of tipulid (a) and chironomid larvae (b) (Diptera). Scale = 1 mm.

Chapter 14 Order Collembola

Collembola, or springtails, is widespread in the world and usually found in terrestrial habitats. They are tiny (usually less than 3 mm long), and the integument is water-repelling, which allows them to float on the surface film of the water. They usually occur in decaying leaf packs where detrital foods are available (Christiansen & Snider, 1996). A collembolan bears a structure called a **collophore** on the ventral side of abdominal segment. The **furcula**, an appendage on the fourth abdominal sternite, aids them in springing or jumping into the air. When it is unused, the furcula is folded upward and held by the **tenaculum** on the third abdominal segment. The knowledge of collembolans in Asia is very limited. Isotomidae (Fig.1) is a common family that is usually found along the margins of streams.

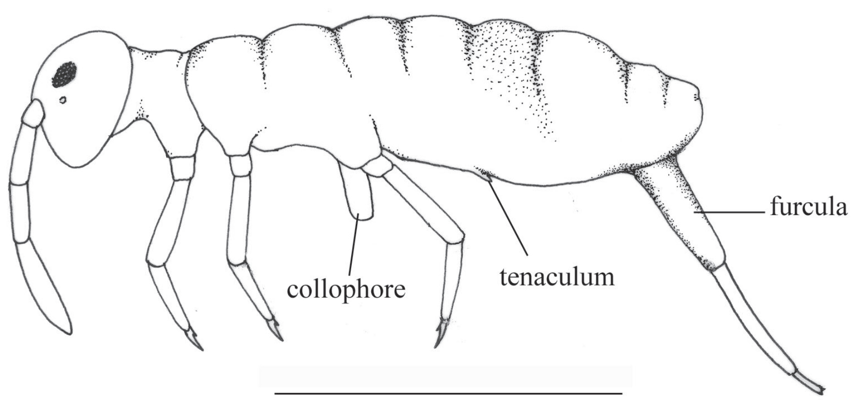


Fig. 1 Lateral view of Isotomidae.
Scale line = 0.5 mm.

Chapter 15 Order Ephemeroptera

The Ephemeroptera, or mayflies, is the most primitive and ancient group of aquatic insects. They have two adult stages, the **subimago** and the **imago**. Both adult stages are short lived and do not feed. Mayflies are cosmopolitan and found in various freshwater habitats ranging from streams and rivers to standing ponds. Taxon richness is greater in lotic habitats. All nymphal stages are aquatic. Nymphs have gills on various abdominal segments, and the last abdominal segment bears three **caudal filaments,** although occasionally the middle one is absent or reduced. Nymphs feed mainly on algae on rock surfaces, on fine-particle detritus or on suspended particles. Only a very few mayflies are predators. Mayflies are used extensively as indicators to assess pollution and environmental change.

Ephemeroptera is a small order of insects, with about 3,000 described species and more than 375 genera and 37 families (Brittain & Sartori, 2003). The ephemeropteran fauna of the Indochina region is relatively poorly studied compared to that of temperate regions (Soldán, 2001). Only the Leptophlebiidae, Neoephemeridae and Potamanthidae have been treated in detail (Peters & Edmund, 1970; Bae & McCaffery, 1991, 1998). To date, approximately 58 genera and species of 18 ephemeropteran families have been recorded from the region, and many unclear taxonomic identifications at the generic level remain. This reflects a need in taxonomic studies for the immature stages to be associated with their respective adults. The following keys of Ephemeroptera of Indochina are modified from several publications (Allen, 1971; Bae & McCafferty, 1991, 1998; Dudgeon, 1999; Hubbard, 1994; Nguyen, 2003; Peters, 1967; Peters & Edmunds, 1970; Sites *et al*., 2001; Soldán & Braasch, 1984).

Key to Families, Genera and Known Species of Mature Mayfly Nymphs (Ephemeroptera) of Indochina

1 Body smooth and hemispherical (beetle-like); all gills and much of the abdomen covered by a thoracic shield (Fig. 1); .... Prosopistomatidae, *Prosopistoma* …2

1′ Body form not as above; abdominal gills partially or completely exposed 5

2(1) Mesonotum with posterior and anterior dark brown band separated, with light band as wide as anterior dark one (Fig. 1) .... *P. funanense*

2′ Mesonotum with connected band with numerous pale spots or bands separated by narrow W-shaped lighter band (Fig. 2a, 3a) 3

3(2′) Antennae 4 segmented (Fig. 2c); apical segment of maxillary palps longer than 1/3 length of segment II (Fig. 2b)... *P. sinense*

3′ Antennae usually 5 segmented (sometimes 4 segmented, if 4 segmented they have apical segment of maxillary palps a little shorter than 1/3 length of segment II) ... 4

4(3′) Apex of inner margin of fore tibiae with 6 or 7 serrated spines (Fig. 3c); segment III of maxillary palps a little shorter than 1/3 length of segment II (Fig. 3b)............ .... *P. annamense*

4′ Apex of inner margin of fore tibia with 8 equal-sized fine serrated spines (Fig. 4b); segment III of maxillary palps a little longer than 1/3 length of segment II .... *P. wouterae*

5(1′) Head and prothorax with conspicuous crown of bristles; without mandibular tusks; gill ventral; legs are modified for burrowing (Fig. 6a) .... BEHNINGIIDAE…6

5′ Head and prothorax lacking crowns of bristles; mandibular tusks present (Fig. 7b); gill lateral or dorsal; legs not modified for burrowing.. 7

6(5) Tibiae of hindlegs not reduced (Fig. 5b), tarsi of forelegs fused to tibiae (Fig. 5a), claw present ....*Protobehningia* (*P. merga*)

6′ Tibiae of hindlegs reduced (Fig. 6b), tarsi of forelegs not fused to tibiae (Fig. 6a), claw absent ....*Behningia*

7(5′) Mandibles with tusk-like projection (except some species of *Afromera* (Fig. 17) bear atrophied tusk); gill II-VII double and uniform in structure with fringed margin (Fig. 7a,8,16a), gill I variable 8

7′ Mandibles without tusk-like projection, gills otherwise 19

8(7) Legs slender for running or crawling, tibiae cylindrical; gills project laterally (Fig. 7a) 9

8′ Legs (especially tibiae) robust or flattened for digging; gills angled backwards dorsally over the body (Fig. 16a).. 14

9(8) Mandibular tusks with numerous distinct long setae (Fig. 7b); caudal filaments with inconspicous fine setae (Fig. 7a)...................................EUTHYPLOCIIDAE, *Polyplocia*

9′ Mandibular tusks lacking long setae (Fig. 8) or have only inconspicuous setae (Fig. 9b); caudal filaments with distinct long setae .... POTAMANTHIDAE…10

10(9′) Mandibular tusks roughly equal to or longer than the length of the head................. .... *Rhoenanthus*...11

10′ Mandibular tusks shorter than one half of the length of the head (Fig. 8) .... *Potamanthus* (*Potamanthodes)* (*P. formosus*)

11(10)` Mandibular tusks with a large lateral spine (so that the tusks appear forked) (Fig. 10); maxillary palp slender, with weakly-developed setae on the terminal segment ....*Rhoenanthus (Rhoenanthus)*…12

11′ Mandibular tusks lack a large lateral spine (not appearing apically forked) (Fig. 9a-b), but sometimes have a small lateral spine; mandibular tusks strongly convergent and abruptly curved inward; maxillary palp thick, with strongly-developed setae on the terminal segment....................................... *Rhoenanthus (Potamanthindus)*...13

12(11) Leg unicolorous, at most with diffuse smudges; 28-46 simple stout setae and 4-5 bipectinte hair-like setae laterally on mandibles; no medial row of spines developed (Fig. 10) .... *R. (R.) speciosus*

12′ Leg with conspicuous dark marking (band and stripes) (Fig. 11b); 40-55 simple stout setae and about 15 simple hair-like long setae laterally on mandibles (Fig. 11c); bipectinate setae absent; medial row of 15-20 spines well developed...... ....*R. (R.) distafurcus*

13(11′) Mandibular tusks greatly long (1.4x length of head), gradually curved inward; body large (18.2-21.2 mm)...*R. (P.) magnificus*

13′ Mandibular tusks moderately long (0.8x length of head), abruptly curved inward; body medium sized (12.5-16.7 mm)..*R. (P.) obscurus*

14(8′) Tusks curved inwards, inner edges concave (Fig. 12)............. Polymitarcyidae...15

14′ Tusks curved outwards, inner edges convex (Fig. 16b) 16

15(14) Slender tusk with setae and small tubercles (Fig. 12) ; a single gill on abdominal segment I.. *Ephoron*

15′ Broad and flat tusks which are strongly toothed close to the apex (Fig. 13)............. ....*Povilla*

16(14′).....Broad, flat tusks with outer edge notched; tusks with shallow indentation along outer margin (Fig. 15a-b)...Palingeniidae

16′ Tusks smooth and slender (Fig. 14,16b).......................................Ephemeridae...17

17(16′) Frontal process on the head reduced; rather inconspicuous and not bifid (Fig. 14); mandibular tusks are triangular in cross-section; tarsal claws on forelegs reduced relative to those of the mid- and hindlegs...*Eatonigenia*

17′ Frontal process on the head well-developed and bifid (Fig. 16b); mandibular tusks are circular in cross-section; tarsal claws on forelegs not reduce 18

18(17′) Mandibular tusks well-developed (Fig. 16a-b); abdominal gill I with two lobes of roughly equal size...*Ephemera*

18′ Mandibular tusks reduced or atrophied (Fig. 17); abdominal gill I asymmetrical with a relatively large outer lobe ....*Afromera*

19(7′) Gills on abdominal segment II large and plate-like (operculate) (Fig. 18a, 19).... 20

19′ Gills on abdominal segment II not greatly enlarged... 27

20(19) Gills on abdominal segment II meet along the midline (Fig. 18a, 19)...................... ....Neoephemeridae, *Potamanthellus*...21
20′ Gills on abdominal segment II overlap along the midline (Fig. 20a)........................ ....Caenidae...23

21(20) Operculate gills with diagonal ridge (Fig. 18a)...22
21′ Operculate gills without diagonal ridge (Fig. 19)...................................*P. edmundsi*

22(21) Dorsal fore femora with transverse row of setae (Fig. 18b), abdominal terga VI-VIII with distinct posteromedian tubercle...*P. caenoides*
22′ Dorsal fore femora without transverse row of setae, abdominal terga VI-VIII with rumidentary posteromedian tubercle ....*P. amabilis*

23(20′) Head with ocelli on raised tubercles (Fig. 20b) 24
23′ Head lacks ocular tubercles (although ocelli are present) 25

24(23) Femora wide (three times wider than the tibiae); fore coxae nearly contiguous; maxillary and labial palps with 3 segments (Fig. 20c); posterolateral spines on abdomen segments IV-VII (Fig. 20a) ....*Caenoculis*
24′ Femora narrow (no more than twice as the tibiae); fore coxae widely separated; maxillary and labial palps with 2 segments; posterolateral spines on abdomen segments III-VI, those on segment VI are strongly bent medially (Fig. 21a-b); the anterior margin of the mesosternum bear numerous long bristles........*Cercobrachys*

25(23′) Fore tibiae with two transverse rows of filtering setae (Fig. 22), long setae protruding from the front of the head between and below the antennae; gill covers with a simple ridge ....*Clypeocaenis*
25′ Fore tibiae without two transverse rows of filtering setae; gill covers may have a triangular or Y-shaped ridge (Fig. 23a-b) 26

26(25′) Gill covers with stout spines on the mesal fork of the triangular ridge; submarginal spine lacking but marginal fringe of hairs is present (Fig. 23b) .... *Caenodes*
26′ Gill covers without stout spines on the upper surface, but a row of submarginal spines is present ....*Caenis*

27(19′) ..Forelegs with conspicuous rows of long setae along the inner margins of femora and tibiae (Fig. 25b)...28
27′ Forelegs without rows of long setae along the inner margins 29

28(27) Body flat, gills are rather small (Fig. 24) ....Oligoneuriidae, *Chromarcys*
28′ Body streamlined (Fig. 25a), possession of coxal gill tufts (Fig. 25b)...................... ....Isonychidae, *Isonychia*

29(27′) Flat plate-like head, with dorsally situated eyes, concealing the mouthparts when viewed from above; body dorsoventrally compressed (Fig. 29a, 30a, 32a) .... HEPTAGENIIDAE...30
29′ Mouthparts clearly visible from above; head not plate like 41

30(29) Two filaments at the end of the abdomen.. 31
30′ Three filaments at the end of the abdomen... 32

31(30) Gills I-VII modified to form 'sucking disc' (Fig. 26)....................................... *Iron*
31′ Gills I-VII not modified to form 'sucking disc (Fig. 27).............................*Epeorus*

32(30′) Gills overlap ventrally to form a 'sucking disc' (Fig. 28)................... *Rhithrogena*
32′ Gills not as above 33

33(32′) Gill I with tracheal tufts well developed and lamellae reduced or vestiged 34
33′ Gill not as above 35

34(33) Labrum laterally elongated; lamellae of gill III vestigial; lamellae of gill VII with hairs on lateral margin (Fig. 29a-e) .... *Trichogenia* (*T. maxillaris*)
34′ Labrum laterally triangular; lamellae of gill III developed; lamellae of gill VII without hairs ....*Paegniodes*

35(33′) Spiniform lateral process on segments II-VIII well develop (Fig. 30a-b) .... *Thalerosphyrus*
35′ Lateral processes less well develop or lacking.. 36

36(35′) Lamellae of gills V and VI with pointed apical prolongation (Fig. 31a-b)............. ....*Cinygmina*
36′ Gills lamellate without apical prolongation... 37

37(36′) Gill VII lanceolate with pointed tip, 3x longer than broad and without tracheal tufts (Fig. 33a-b)...*Asionurus* (*A. primus*)
37′ Gill VII not lanceolate, not more than twice as long as broad, with or without tracheal tufts 38

38(37′) Fore femora with patches of stout setae on dorsal surface; gill VII with tracheal tufts ....*Compsoneuria* (*C. thienemanni*)
38′ Fore femora without patches of stout setae on dorsal surface; gill VII with or without tracheal tufts 39

39(38′) Caudal filaments with alternating segmented of light and dark bands.................... .... *Ecdyonurus*
39′ Caudal filament not as above 40

40(39′) Cerci bear spines as well as lateral bristles and segments of the cerci with stout spines alternate with those lacking such spines (Fig. 32); gills I-VII with row of sparse marginal set.. *Rhithrogeniella* (*R. tonkinensis*)
40′ Cerci not as above; gills I-VII without row of sparse marginal setae .... *Afronurus*

41(29′) Gills on abdominal segment II absent (Fig. 34-39) ................EPHEMERELLIDAE...42
41′ Gills on abdominal segment II present (Fig. 44, 45) 54

42(41) Larvae with lamellate gills on abdominal segment III-VI; gill III operculate and completely covers the rest of the gill series; head bears tubercle (Fig. 34)............... .... *Hyrtanella*
42′ Larvae with lamellate gills on abdominal segment III-VII; gill III maybe semioperculate but does not cover the rest of the gill series completely; head may or may not bear tubercle or spine 43

43(42′) Gills on segment III-VII; gill III enlarged and semioperculate, covering most of remaining gills; maxillary palpi absent .... *Torleya*
43′ Gills on segment III-VII; gill III not enlarged as above; maxillary palpi developed or absent.. 44

44(43′) Femora of mid- and hindlegs expanded and much broader than those of the forelegs; anterolateral corners of the pronotum projecting forward, and the anterior portion of the mesonotum is expanded (Fig. 35-38) .... *Cincticostella*...45
44′ Femora of forelegs either at least as broad or broader than those the mid- and hindlegs; pronotum and mesonotum not projecting or expanded.......................... 48

45(44) Middle and hind femora narrow and margin entire; head without suboccipital tubercles; head with three pale maculae on fronts; maxillae without palpi (Fig. 35). .... *C. gosei*
45′ Middle and hind femora expand and margin serrate; head with suboccipital tubercles.. 46

46(45′) Abdominal terga with paired submedian tubercles on segments I-X (Fig. 36a); fore femora with median band of tubercles; head, body and legs with numerous pale spots (Fig. 36b-c) .... *C. insolta*
46′ Abdominal terga with paired submedian tubercles on segments II-X; fore femora without median band of tubercles; head, body and legs without numerous pale spots 47

47(46′) Head quadrangular; abdominal terga with paired submedian tubercles on segments II-X (Fig. 37) .... *C. boja*

47′ Head round; abdominal terga with paired submedian tubercles on segments IV-IX (Fig. 38) .... *C. femorata*

48(44′) Body and appendages covered with long setae (Fig. 39); body lacks tubercles; mandibles are asymmetrical ....*Crinitella*

48′ Body not covered with long setae; body with tubercles or spines on the head, thorax or the abdomen 49

49(48′) Head with spines or tubercles (Fig. 40a); fore femora usually expanded, bearing spines along the anterior margin (Fig. 40b); body robust............................*Drunella*

49′ Head lacks spines or tubercles; fore femora not markedly expanded and without spines along the anterior margin.. 50

50(49′) Apical mandibular tooth greatly elongated and extending beyond anterior margin of head (Fig. 41) ....*Kangella* (*K. brocha*)

50′ Apical mandibular tooth not greatly elongated and not extending beyond anterior margin of head 51

51(50′) Mesonotum with an anterolateral spine or projection (Fig. 42)....*Ephacerella*…52

51′ Mesonotum lacks lateral spines or projections... 53

52(51) Mesonotum with long, acute anterolateral spine and without dorsal tubercles .... *E. longicaudata*

52′ Mesonotum with rudimentary anterolateral spine and with 5 dorsal tubercles.......... ....*E. commodema*

53(51′) Abdominal terga lack paired tubercles; dorsal surface of the body strongly marked with paired longitudinal stripes (Fig. 43) ....*Uracanthella*

53′ Abdominal terga with paired tubercles; body *may* lack stripes; maxillary palpi absent.. *Serratella*

54(41′) Gills borne dorsally on abdominal segment II-VII 57

54′ Gills borne laterally on abdominal segment I-VII.. 55

55(54′) Median caudal filament absent; posterior margin of abdominal terga I-X each with mid-dorsal tubercle (Fig. 44)......................TELOGANODIDAE, *Teloganodes* (*T. tristis*)

55′ Median caudal filament present.. 56

56(55′) Lamellate gills on segment II-VII; head with cephalic horns (Fig. 45) ....Vietnamellidae, *Vietnamella* (*V. thani*)

56′ Posterior margin of abdominal terga IV-VI forming mid-dorsal notch; terga II-IX expanded laterally and well developed projection (Fig. 46); head without cephalic horn...Teloganellidae, *Teloganella* (*T. umbrata*)

57(54) Head rectangular; gills various types; terminal filament well-developed (Fig. 49, 50, 52, 53).. Leptophlebiidae...58

57′ Head round, gills lamellate or plate-like (Fig. 54-59); perminal filament sometimes reduced or lacking (Fig. 56, 57) .... Baetidae...64

58(57) Abdominal terga extending around to venter of abdomen on segments III-VII (Fig. 47) ....*Isca*

58′ Abdominal terga extending to lateral sides of abdomen, all abdominal gills lateral or dorsal 59

59(58′) Maxillary and labial palpi greatly elongated and extending beyond side of head (Fig. 48); gills present on abdominal segments II-VII, denticle of claws about equal length .... *Choroterpides*

59′ Maxillary and labial palpi not greatly elongated and usually not extending beyond side of head.. 60

60(59′) Middle abdominal gills plate-like with fringed margin (Fig. 49)..............*Thraulus*

60′ Middle abdominal gills without a fringed margin, *may be* plate or leaf-like, or bifurcate and long and slender.. 61

61(60′) Gill I similar to others in the series (Fig. 50) ....*Habrophlebiodes*

61′ Gill I differing from the others 62

62(61′) Posterolateral spine on abdominal segments III-IX, those on VIII and IX with curved inner edge (Fig. 51b), a large tooth-like process on the anterior apex of the maxilla (Fig. 51a) .... *Cryptopenella*

62′ Posterolateral spine on abdominal segments IV or V-IX; spine on segments VIII and IX not as above, no large tooth-like process on the anterior apex of the maxilla as above (Fig. 52a).. *Choroterpes*…63

63(62′) Abdominal gills III-VII terminate in 3 slender, subequal process (Fig. 53)............ .... *Choroterpes (Euthraulus)*

63′ Abdominal gills III-VII terminate in 3 processes, with middle one being longer than laterals (Fig. 52b).. *Choroterpes (Choroterpes)*

64(57′) Abdominal gills on one or more segments bilamellate (double) (Fig. 54,55)...... 65
64′ All abdominal gills single (Fig. 56-59) 66

65(64) Lamellae of gills I-VI doubled (Fig. 54), but gill VII is single.....................*Cloeon*
65′ Lamellae of gills I-V distinctly asymmetrical and bear small dorsal flap (Fig. 55), gills VI-VII are single...*Procloeon*

66(64′) Terminal filament absent or reduced, always shorter than 0.5x cerci (Fig. 58) .. 67
66′ Terminal filament developed, always longer than 0.5x cerci (Fig. 60) 71

67(66) Abdominal terga with spiniform tubercles (Fig. 56) 68
67′ Abdominal terga without spiniform tubercles (Fig. 59) 70

68(67) The tergites of the metathorax and the abdomen (I-IX) bear a single median spiniform tubercle (Fig. 56a) ....*Gratia*...69
68′ The tergites bear single median (I-III) or paired submedian dorsal tubercles (IV-IX) (Fig. 58); apex of labial palp conical ....*Baetiella*

69(68) Glossae subequal to paraglossae in length; margin of gills with both scales and setae (Fig. 57) .... *G. sororculaenadinae*
69′ Glossae shorter than paraglossae ; margin of gills with fine setae (Fig. 56b) .... *G. narumonae*

70(67′) Terminal filament shorter than 1/2 length of cerci (Fig. 59a); margin of gills smooth, without setae (Fig. 59b) .... *Platybaetis*
70′ Terminal filament shorter than 1/4 -1/6 length of cerci; margin of gills with simple hair-like setae (Fig. 60)..*Acentrella*

71(66′) Labium with the 2nd and 3rd palpal segments almost completely fused together to form one large stout segment; tarsal claws without teeth and strongly hooked at apex (nymph lives in bivalves)..*Symbiocloen* (*S. heardi*)
71′ Labium not as above.. 72

72(71′) Venter of thorax with distinct thread-like thoracic gills attached near base of forelegs or hindlegs (Fig. 61b) ....*Heterocloeon*
72′ Venter of thorax without thread-like thoracic gills 73

73(71′) Dorsal surface of all tibiae with long transverse hair like setae (Fig. 62)............... .... *Centroptella*
73′ Dorsal surface of all tibiae without long transverse hair like setae 74

74(73′) Labial palpi enlarged, terminal segment of maxillary palpi excavate .... *Labiobaetis*

74′ Labial palpi not enlarged, terminal segment of maxillary palpi not excavate....... 75

75(74′) Body colour dark brown, posterior margin of abdominal segment V with row of acute spines (Fig. 63)... *Nigrobaetis*

75′ Body colour light brown, posterior margin of abdominal segment V with row of blunt setae (Fig. 64).. *Baetis*

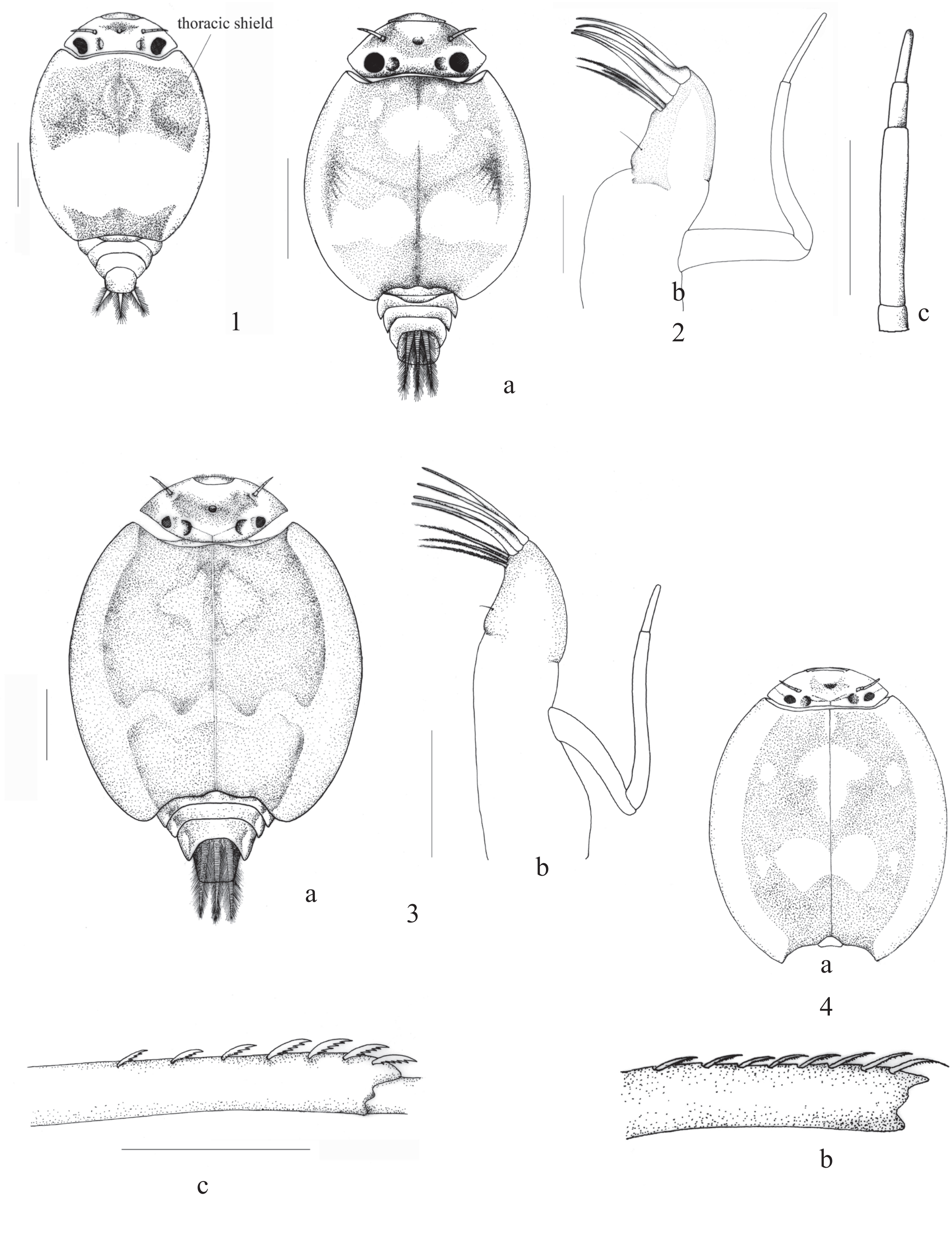


Fig. 1-4 1. Dorsal view of nymph of *Prosopistoma funanense* (redrawn from Soldán & Braasch, 1984, fig. 1); 2. Dorsal view of nymph (a), maxillary palp (b) and antenna (c) of *P. sinense*; 3. Dorsal view of nymph (a), maxillary palp and (b) apex of inner margin of fore tibiae (c) of *P. annamense*; 4. Dorsal view of nymph (a) and apex of inner margin of fore tibiae (b) of *P. wouterae* (redrawn from Peters, 1967, fig. 2, fig. 6).
Scale: (2b, 2c, 3b-c) 0.5 mm; (1, 2a, 3a) 1 mm

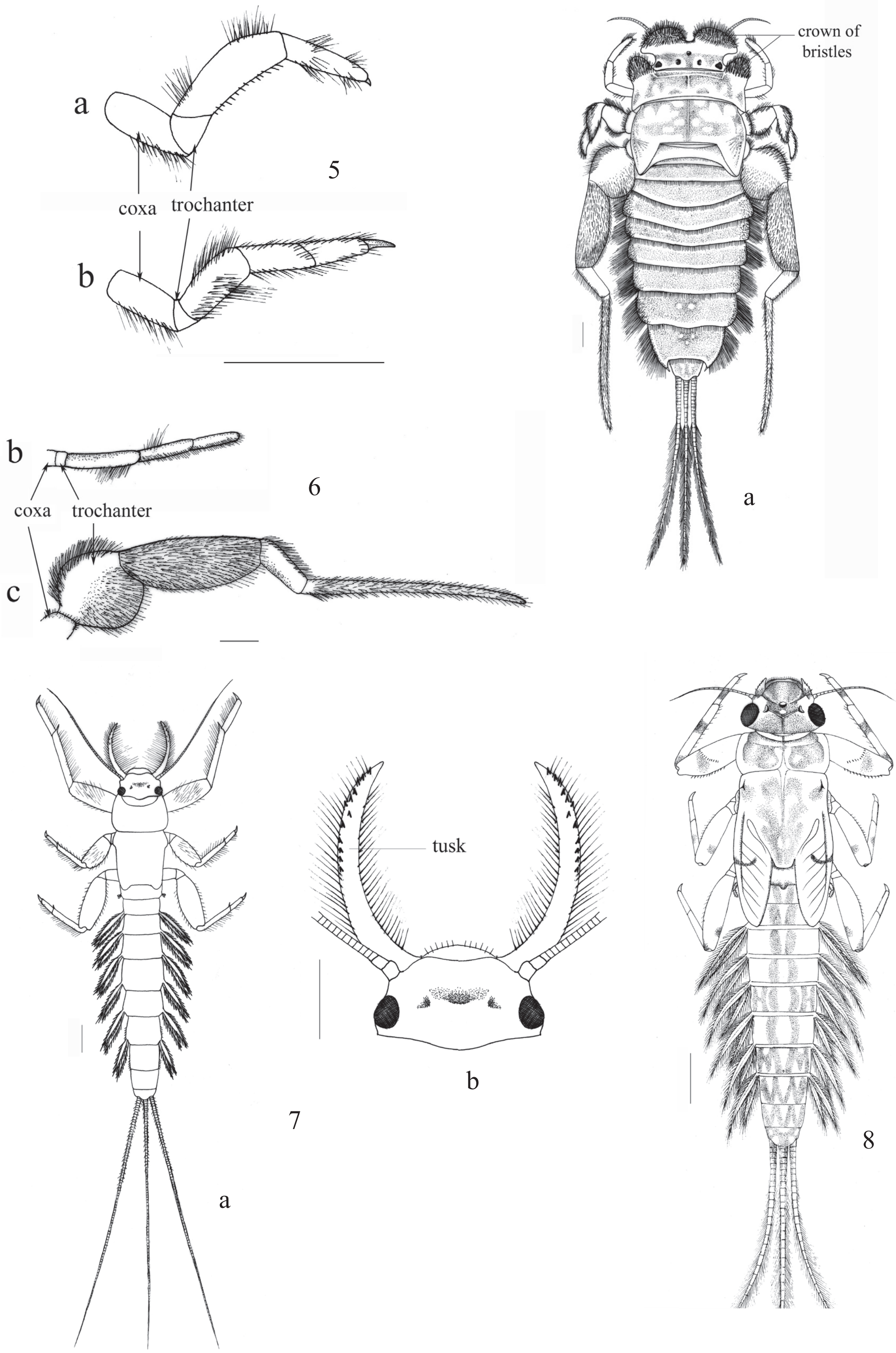


Fig. 5-8 5. Foreleg (a) and hindleg (b) of *Protobehningia merga*; 6. Dorsal view of nymph (a), foreleg (b) and hindleg (c) of *Behningia* sp.; 7. Dorsal view of nymph (a) and dorsal view of head (b) of *Polyplocia* sp.; 8. Dorsal view of nymph of *Potamanthus (Potamanthodes) formosus*.
Scale = 1 mm.

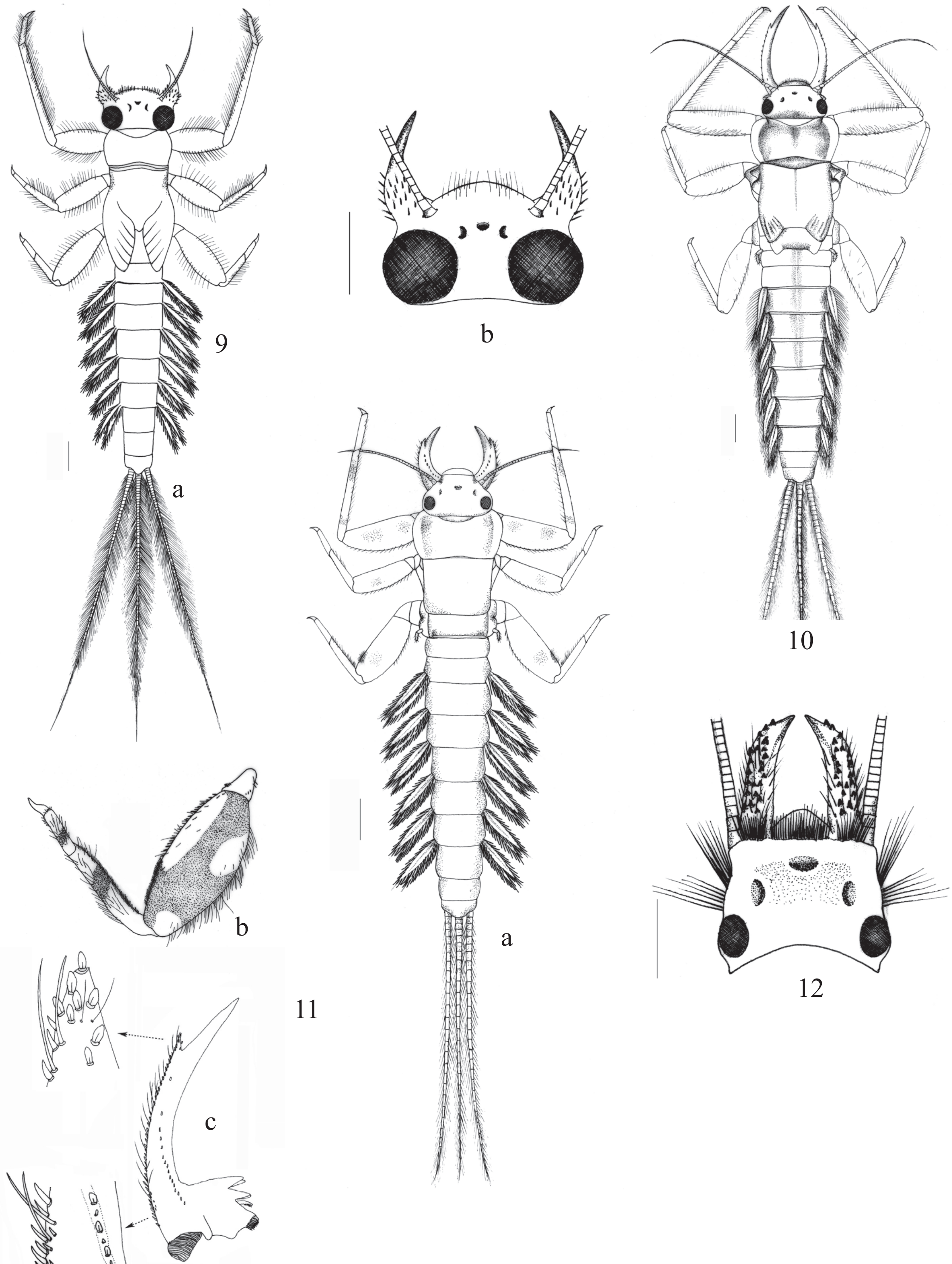


Fig. 9-12 9. Dorsal view of nymph (a) and dorsal view of head (b) of *Rhoenanthus (Potamanthindus) obscurus*; 10. Dorsal view of nymph of *Rhoenanthus (Rhoenanthus) speciosus*; 11. Dorsal view of nymph (a), dorsal view of hind leg (b) and mandibular tusk (c) of *R. (R.) distafurcus* (redrawn from Soldán & Putz, 2000, fig. 3, fig. 10); 12. Dorsal view of head of *Ephoron* sp.
Scale = 1 mm.

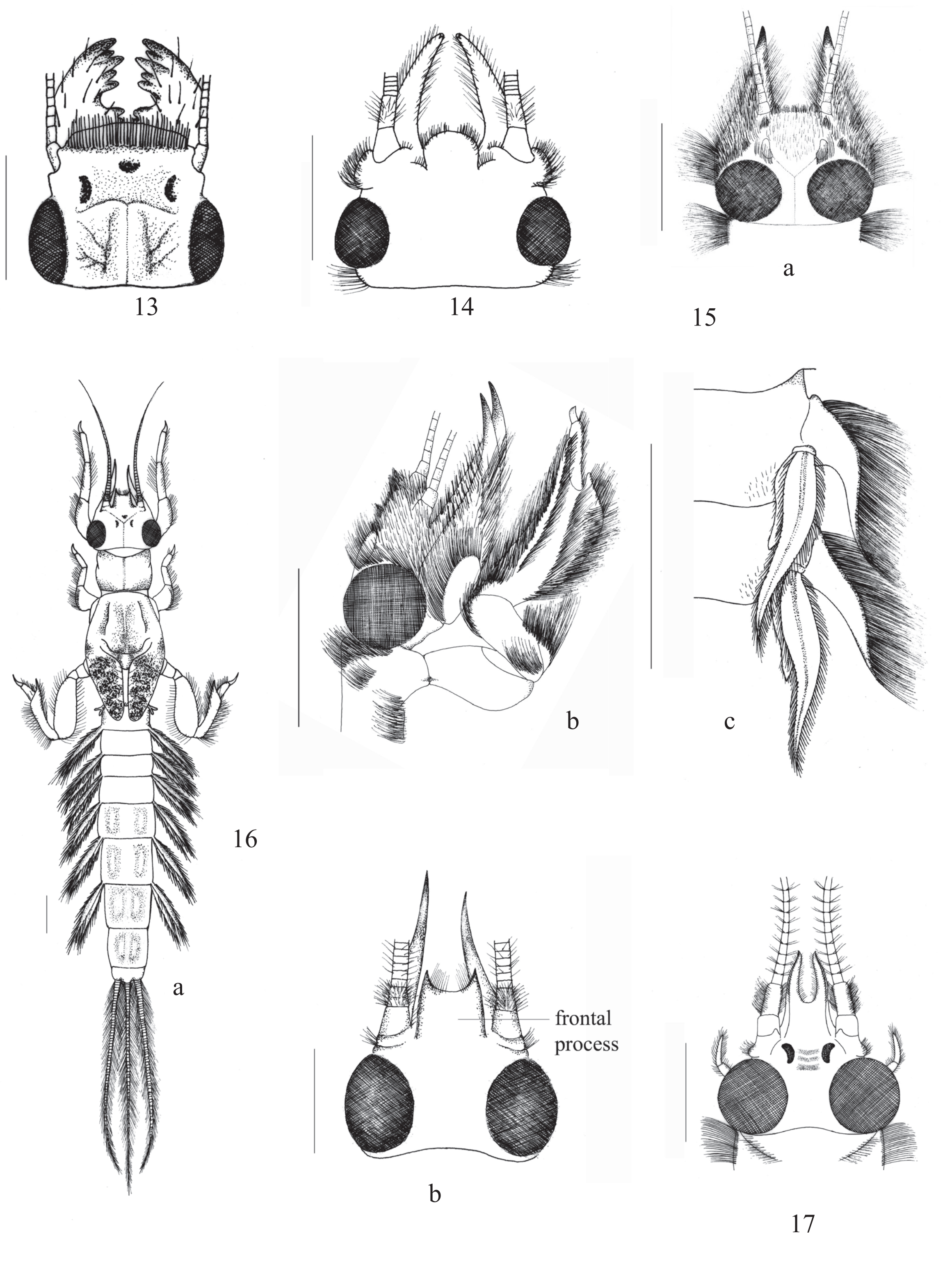


Fig. 13-17 13. Dorsal view of head of *Povilla (Povilla)* sp.; 14. Dorsal view of head of *Eatonigenia* sp. 15. Dorsal view of head (a), side view of head (b) and right abdomen (c) of Palingeniidae; 16. Dorsal view of nymph (a) and dorsal view of head (b) of *Ephemera (Ephemera)* sp.; 17. Dorsal view of head of *Afromera* sp. Scale = 1 mm.

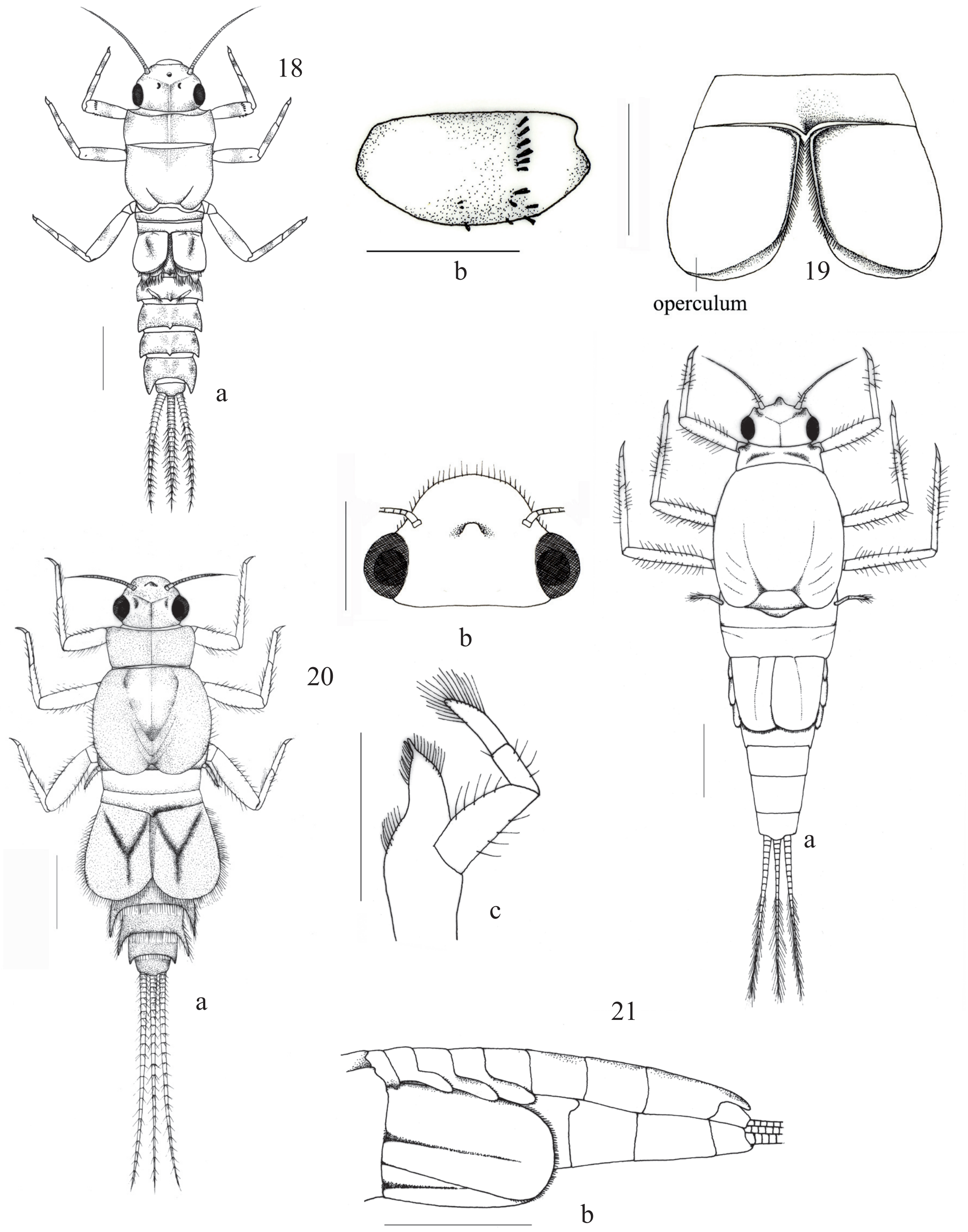


Fig. 18-21 18. Dorsal view of nymph (a) and dorsal view of fore femora (b) of *Potamanthellus caenoides*; 19. Dorsal view of opercular gills of *P. edmundsi*; 20. Dorsal view of nymph (a), dorsal view of head (b) and maxilla (c) of *Caenoculis* sp.; 21. Dorsal view of nymph (a) and side view of abdomen (b) of *Cercobrachys* sp.
Scale: (18b, 20c, 21b) 0.5 mm; (18a, 19, 20a-b, 21a) 1 mm.

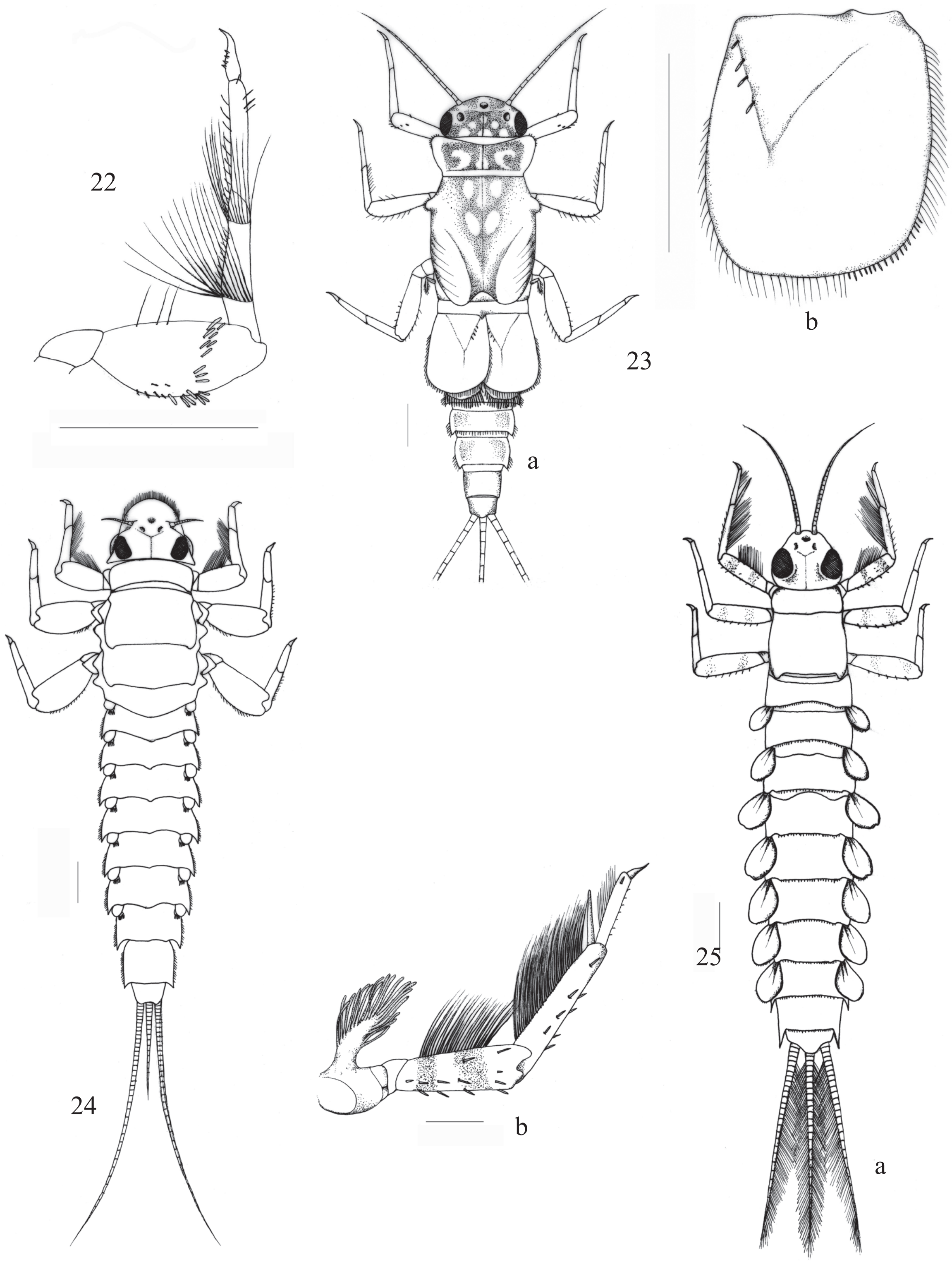


Fig. 22-25 22. Dorsal view of fore leg of *Clypeocaenis* sp.; 23. Dorsal view of nymph (a) and dorsal view of gill cover (b) of *Caenodes* sp.; 24. Dorsal view of nymph of *Chromarcys* sp.; 25. Dorsal view of nymph (a) and dorsal view of fore leg (b) of *Isonychia* sp.
Scale: (22, 23b) 0.5 mm; (23a, 24, 25) 1 mm.

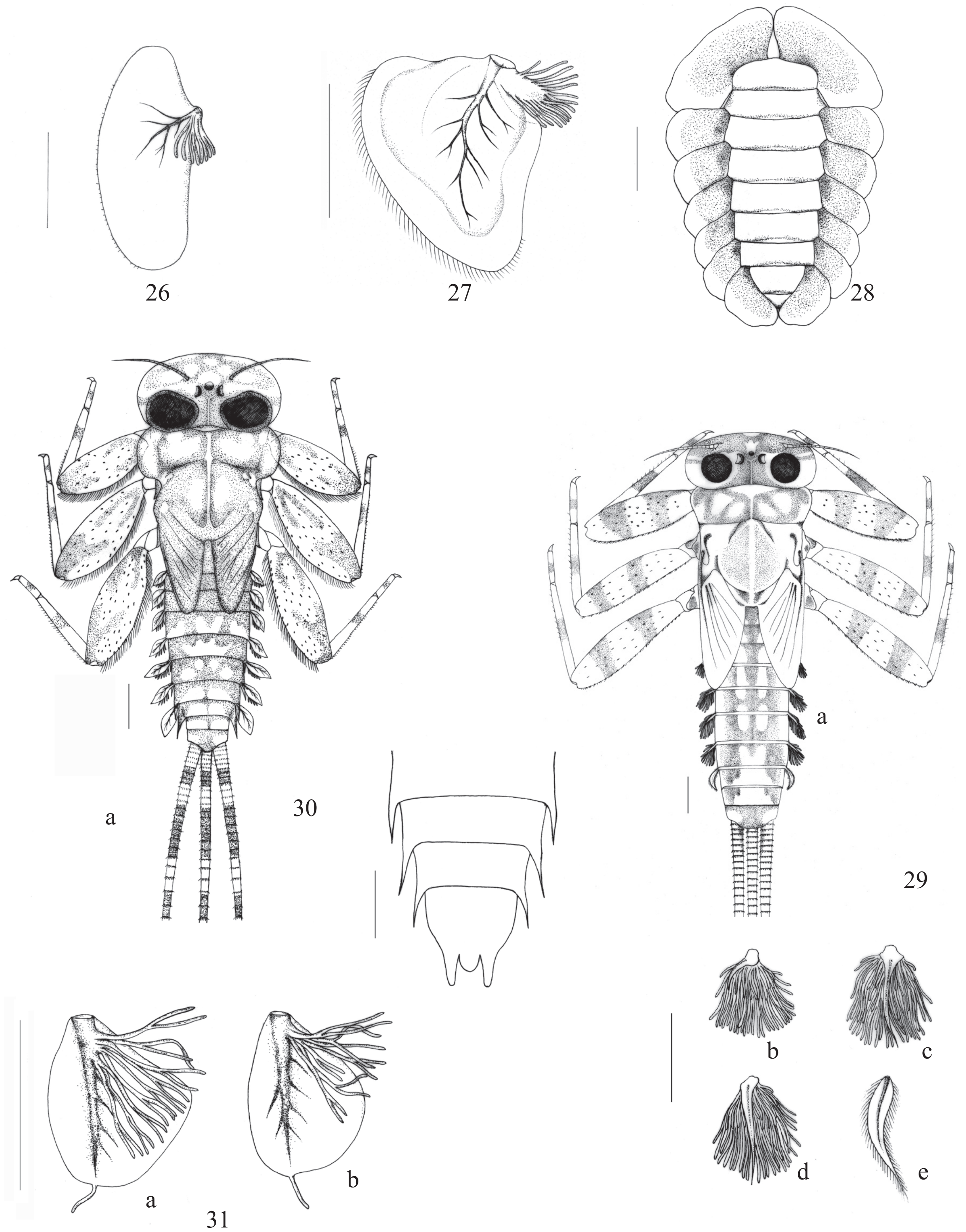


Fig. 26-31. 26. Gill I of *Iron* sp.; 27. Gill I of *Epeorus* sp.; 28. Ventral view of abdomen of *Rhithrogena* sp.; 29. Dorsal view of nymph (a) and gill I (b), III (c), V (d) and VII (e) of *Trichogenia maxillaris*; 30. Dorsal view of nymph (a) and ventral view of abdomen (b) of *Thalerosphyrus* sp.; 31. Ventral view of gills V (a) and VI (b) of *Cinygmina* sp.
Scale: (26, 27, 29b-e, 31) 0.5 mm; (28, 29a, 30) 1 mm.

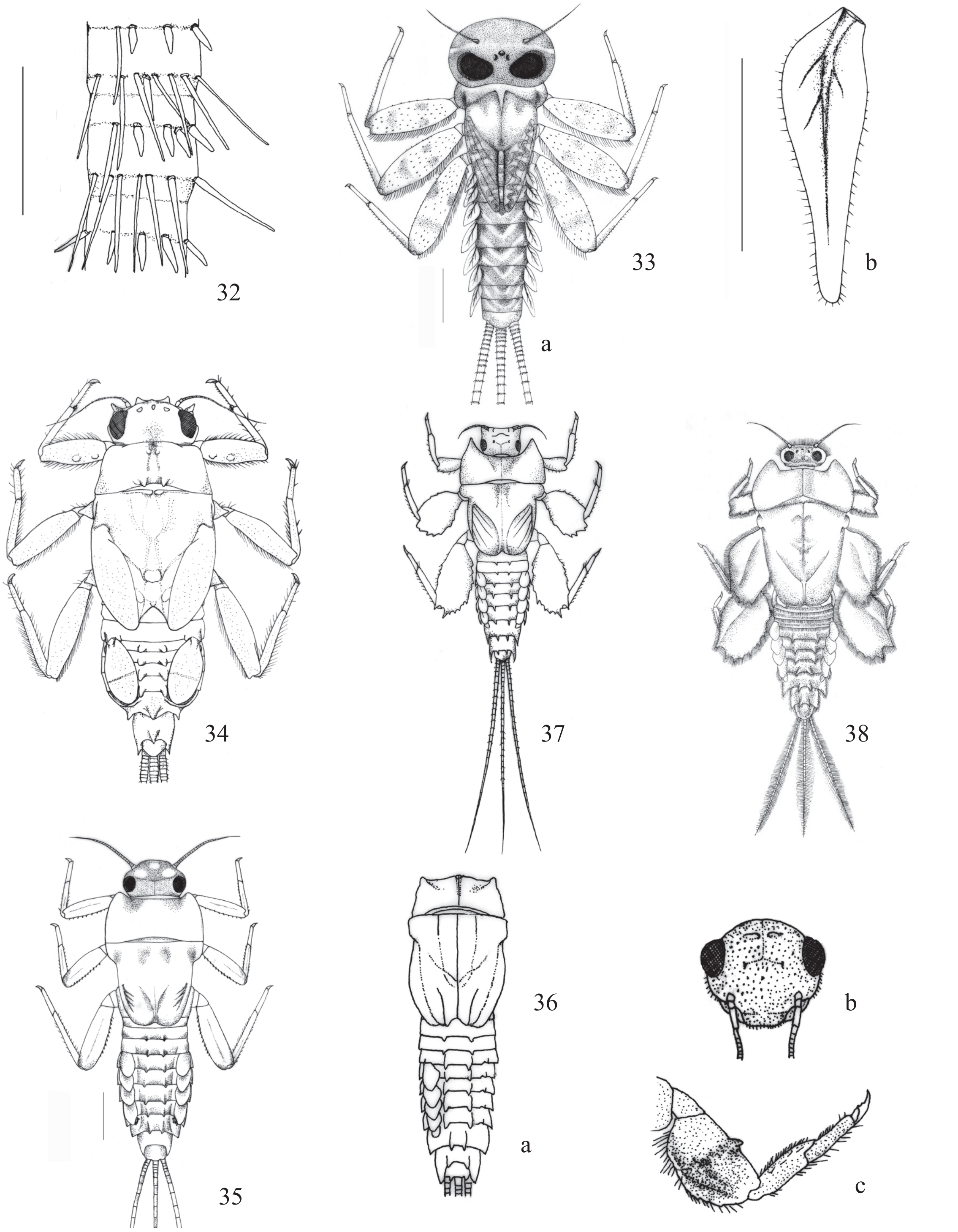


Fig. 32-38. 32. Spines on cerci of *Rhithrogeniella* sp.; 33. Dorsal view of nymph (a) and gill VII (b) of *Asionurus* sp.; 34. Dorsal view of nymph of *Hyrtanella* sp. (redrawn from Allen & Edmunds, 1976, fig.1).; 35. Dorsal view of nymph of *Cincticostella gosei* ; 36. Dorsal view of thorax and abdomen (a) head (b) and fore leg (c) of *C. insolta* (redrawn from Allen, 1971, fig. 12, 14, 18); 37. Dorsal view of nymph of *C. boja* (redrawn from Gose, 1961, fig. 23); 38. Dorsal view of nymph of *C. femorata* (redrawn from Tshernova, 1972, fig. 5).
Scale: (32, 33b) 0.5 mm; (33a, 34, 35, 37, 38) 1 mm.

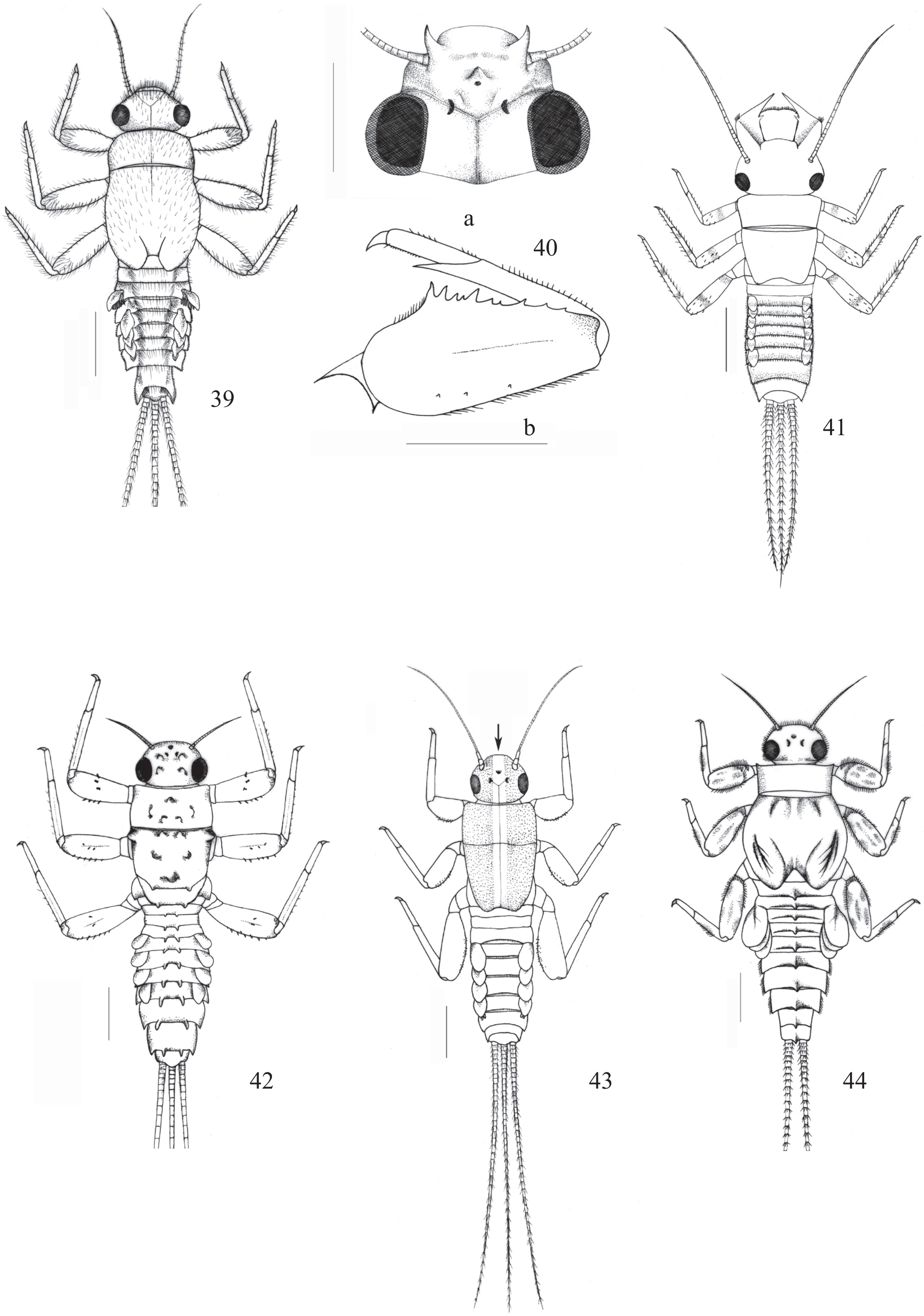


Fig. 39-44 39. Dorsal view of nymph of *Crinitella* sp.; 40. Dorsal view of head (a) and fore femur (b) of *Drunella* sp.; 41. Dorsal view of nymph of *Kangella* sp.; 42. Dorsal view of nymph of *Ephacerella commodema*; 43. Dorsal view of nymph of *Uracanthella* sp.; 44. Dorsal view of nymph of *Teloganodes* sp. Scale = 1 mm.

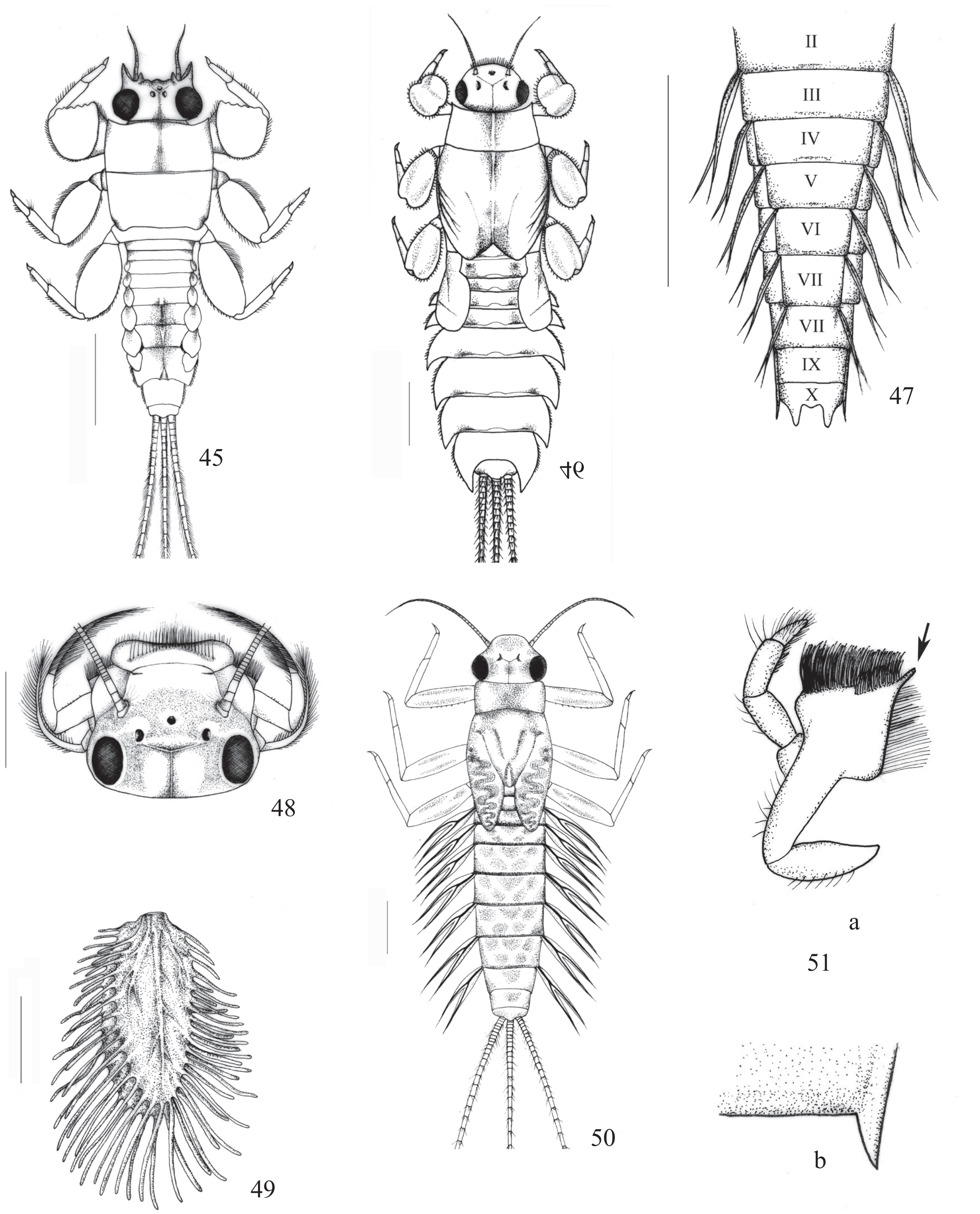


Fig. 45-51. 45. Dorsal view of nymph of *Vietnamella* sp.; 46. Dorsal view of nymph of *Teloganella* sp.; 47. Ventral view of abdomen of *Isca* sp.; 48. Dorsal view of head of *Choroterpides* sp.; 49. Lamellate gill of *Thraulus* sp.; 50. Dorsal view of nymph of *Habrophlebiodes* sp.; 51. Maxilla (a) and posterolateral spine (b) of *Cryptopenella* sp. (redrawn from Peters & Edmunds, 1970, fig. 336, fig. 344). Scale: (49) 0.5 mm; (45-48, 50) 1 mm.

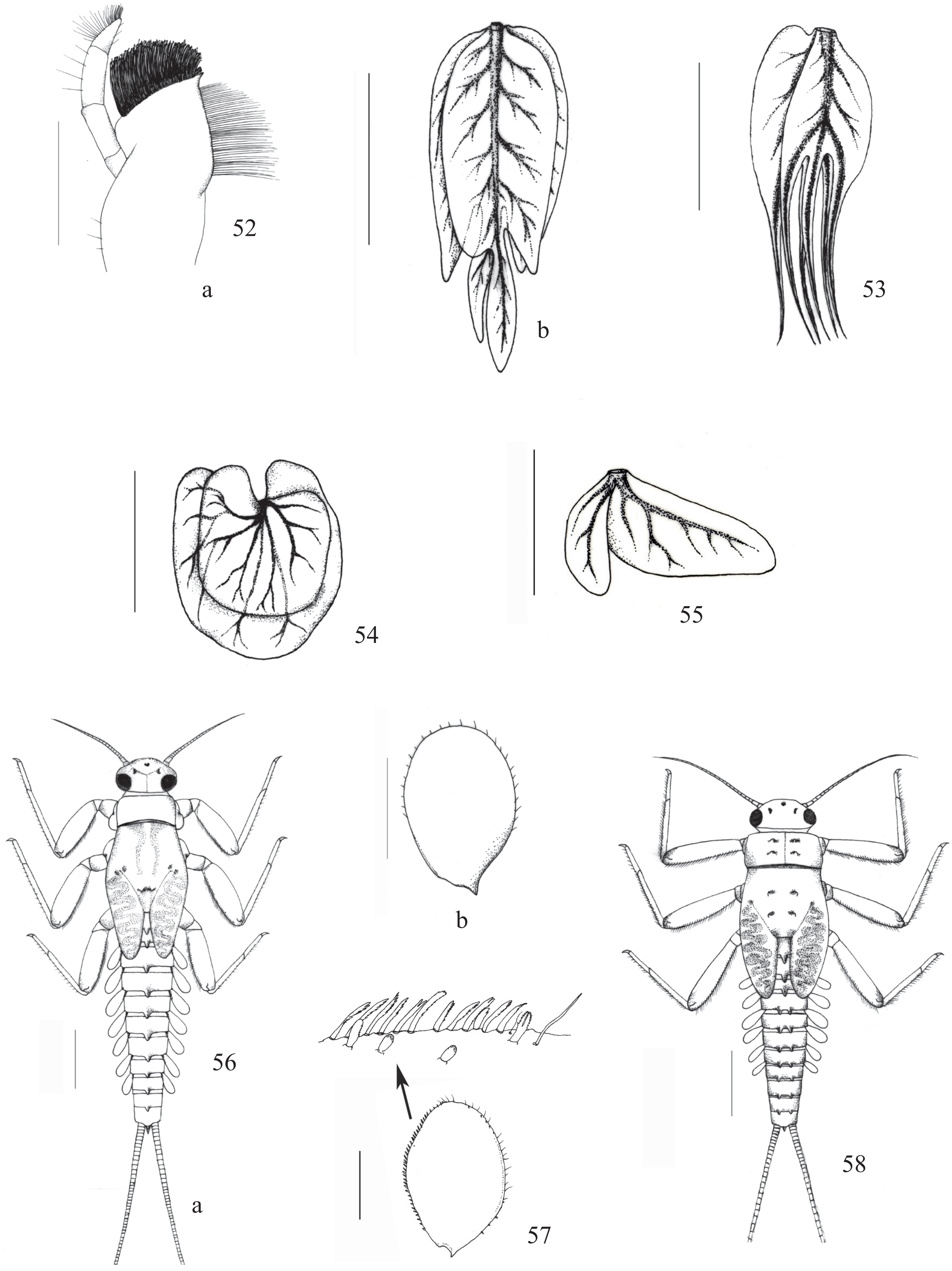


Fig. 52-58 52. Maxilla (a) and gills III-VII (b) of *Choroterpes (Choroterpes)* sp.; 53. Abdominal gills III-VII of *Choroterpes (Euthraulus)* sp.; 54. Gills I-VI of *Cloeon* sp.; 55. Gill of *Procloeon* sp.; 56. Dorsal view of nymph (a) and gill VI (b) of *Gratia narumonae*; 57. Gill VI of *Gratia sororculaenadinae* (redrawn from Thomas, 1992, fig. 16); 58. Dorsal view of nymph of *Baetiella* sp. Scale: (56b, 57) 0.3 mm; (52-55) 0.5 mm; (56a,58) 1 mm.

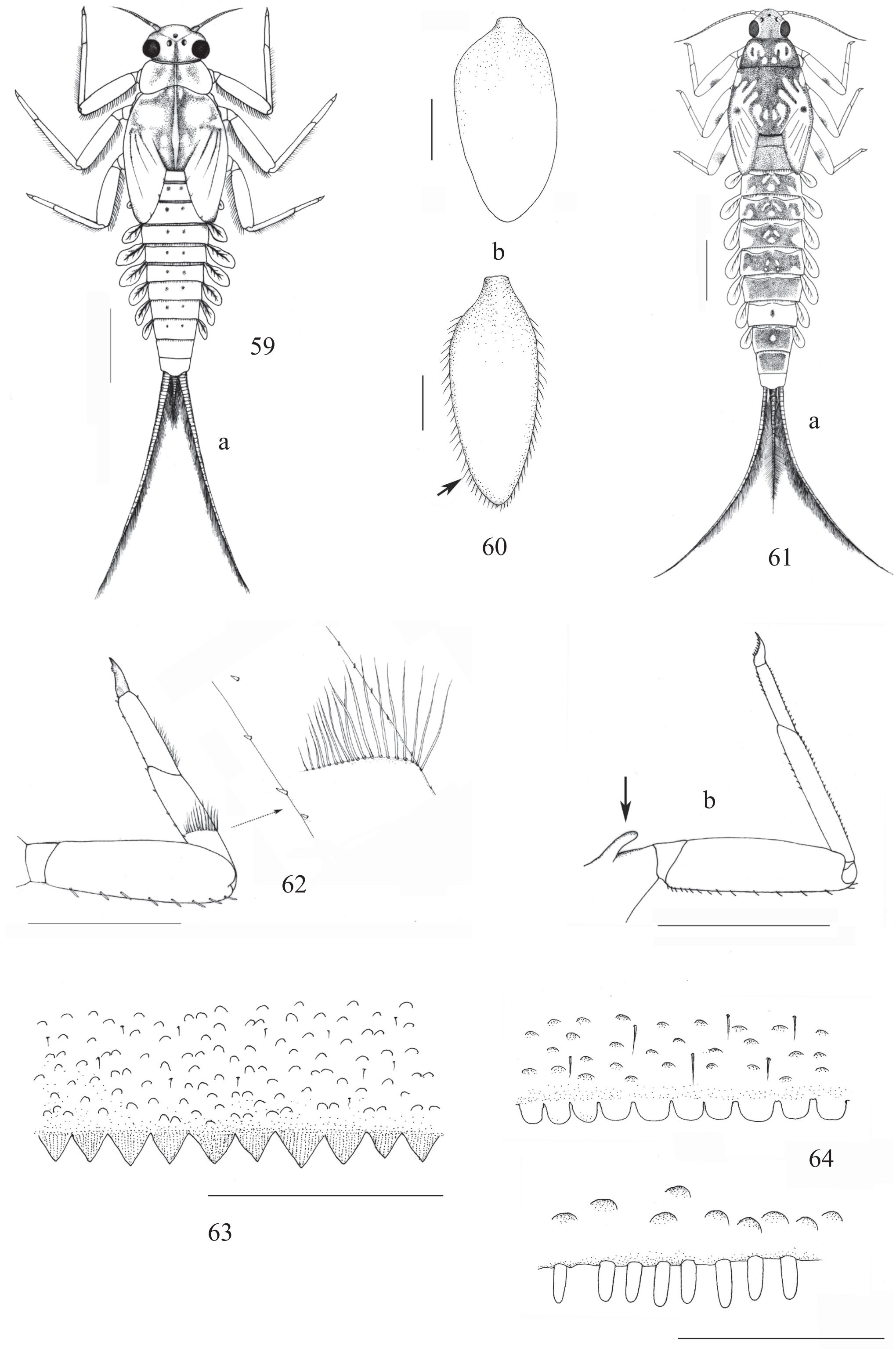


Fig. 59-64 59. Dorsal view of nymph (a) of and gill V (b) of *Platybaetis* sp.; 60. Gill V of *Acentrella* sp.; 61. Dorsal view of nymph (a) and foreleg (b) of *Heterocloeon* sp.; 62. Dorsal view of foreleg of *Centroptella* sp.; 63. Posterior margin of abdominal segment V of *Nigrobaetis* sp.; 64. Posterior margin of abdominal segment V of *Baetis* sp. (modified from Nguyen, 2003, fig. 399,403). Scale: (59b, 60, 63, 64) 0.1 mm; (61b, 62) 0.5 mm; (59a, 61a) 1 mm.

Chapter 16 Order Odonata

The Odonata is one of the primitive and ancient insect orders. It is very diverse and is the second largest aquatic insect order. Nymphs are truly aquatic. Odonata consists of three suborders: Anisoptera, Zygoptera and Anisozygoptera. The first two orders, Anisoptera (or dragonflies) and Zygoptera (or damselflies) are well known. Suborder Anisozygoptera is a small group that occurs in high altitude streams (more than 2,000 msl) in Japan and the Himalayas (Tani & Miyatake, 1979; Kumar & Khanna, 1983).

Adult stages have been well studied (Fraser (1933, 1934, 1936: India and Burma), Hirose & Itoh (1993: Japan), Pinratana *et. al*. (1988: Thailand), Asahina (1993: Thailand)). But knowledge of nymphal stages is limited and taxonomic problems remain. The illustrated book of Japanese dragonfly nymphs by Ishida (1996) is a useful book for identifying nymphs. All nymphal stages of odonates are predators. Nymphs are used as human food in Thailand and Lao PDR. However, they are the intermediate host of the human intestinal fluke *Phaneuropsolus bonnei* (Radomyos, *et, al*., 1992).

Nymphs of odonates have a characteristic labium. It consists of the submentum and prementum, with an elbowed connection, and a pair of labial palps, each palp with a moveable hook. The labium is thrust forwards by hydrostatic pressure and is used to capture prey. Damselfly nymphs have three caudal gills but dragonflies bear rectal gills inside the abdomen. The characteristic labium is an important feature for identification.

Odonates inhabit all types of water bodies, from streams, rivers, swamps, lakes, permanent and temporary ponds to paddy fields. Dudgeon (1999) cites approximately 12 families of Zygoptera and 5 families of Anisoptera in Asia. Adults are well-known but immature stages are not as well described. In the present study a key to families of mature nymphs was constructed.

Key to Families of Mature Odonate Nymphs of Indochina

1 Larva slender, head wider than thorax and abdomen; posterior of abdomen usually with 3 long caudal tracheal gills at the end of abdomen (Fig. 3, 4a, 6a, 7a, 8a, 9a) .. .. suborder Zygoptera...2

1′ Larva stout, head usually narrower than thorax and abdomen; without 3 long caudal lamellae (Fig. 10, 11, 14a, 15a) .... suborder Anisoptera...12

2(1) Antennal segment 1 elongate, as long as the combined length of remaining segments (Fig. 1a); prementum with deep median cleft (Fig. 1b).... Calopterygidae

2′ Antennal segment 1 not elongate, less than the combined length of remaining segments; prementum varies 3

3(2′) Nymphs with 2 caudal gills (Fig. 2) .... Chlorocyphidae
3′ Nymphs with 3 caudal gills 4

4(3′) Abdomen with lateral gills; caudal gills saccoid (Fig. 3) .... Euphaeidae
4′ Abdomen without lateral gills; caudal gills either saccoid or laminate................... 5

5(4′) Caudal gills saccoid, prementum with median cleft.. 6
5′ Caudal gills laminate, prementum with distal margin entire or with median cleft..... 8

6(5) Labial palps with a single seta, without premental setae (Fig. 4b)............................ .... Megapodagrionidae
6′ Labial palps and prementum with many setae... 7

7(6′) Palpal lobe of prementum with simple round teeth .... Platystictidae
7′ Palpal lobe of prementum with 3 sharped teeth, the middle one longest (Fig. 6a-b) .... Amphipterygidae

8(5′) Prementum stalked and spoon shaped (Fig. 5) .... Lestidae
8′ Prementum not stalked, more or less subquadrate or triangular in shape (Fig. b,8b,9b) 9

9 Caudal lamellae with very thick basal and thin distal portions (Fig. 7c); palpal lobe of prementum deeply bifid, inner teeth longer; prementum with 1 seta (Fig. 7b) .... Protoneuridae
9′ Caudal lamellae not divided; palpal lobe of prementum shallowly bifid, the outer portion short, broad apically subtruncate, inner teeth sharp and long................... 10

10(9′) Lamellae nodate or subnodate (Fig. 8c), lateral margin of occiput rounded (Fig. 8d) .... Coenagrionidae
10′ Lamellae denodate , lateral margin of occiput variable.. 11

11(10′) Lamellae with a filamentous fringe (Fig. 9c), lateral margins of occiput slightly angled (Fig. 9a)...Platycnemididae, in part
11′ Lamellae without a filamentous fringe, lateral margins of occiput variable .... Platycnemididae, in part, Coenagrionidae, in part

12(1′) Labium spoon-shaped (Fig. 14b, 15b).. 14
12′ Labium flat.. 13

13(12′) Antennae with 4 segments, segment 3 very large (Fig. 10a-b) ....GOMPHIDAE
13′ Antennae with 6-7 segments, each segment subequal in length (Fig. 11a-b)............. .... AESHNIDAE

14(12) Distal part of each palpal lobe with large irregular teeth (Fig. 12) .... CORDULEGASTRIDAE
14′ Distal part of each palpal lobe smooth or crenuate (Fig. 14b,15b) 15

15(14′) Head with a prominent median horn between bases of antennae; metasternum with tubercle; legs very long, apex of hind femur reaching to or beyond posterior margin of abdominal segment VIII (Fig. 13) ....CORDULIIDAE, MACROMIINAE
15′ Head without a horn between bases of antennae; metasternum without sclerite; legs not so long, apex of hind femur never reaching posterior of abdominal segment VIII 16

16(15′) Distal part of each palpal lobe with shallow indentations; if deep indentation, then lateral spine of abdominal segment VII as long as or longer than midlength of abdominal segment IX (Fig. 14a-b).. LIBELLULIDAE
16′ Distal part of each palpal lobe with deep indentations; without spine on abdominal segment VIII; if spines present, it is shorter than midlength of abdominal segment IX (Fig. 15a-b).. CORDULIIDAE, CORDULIINAE

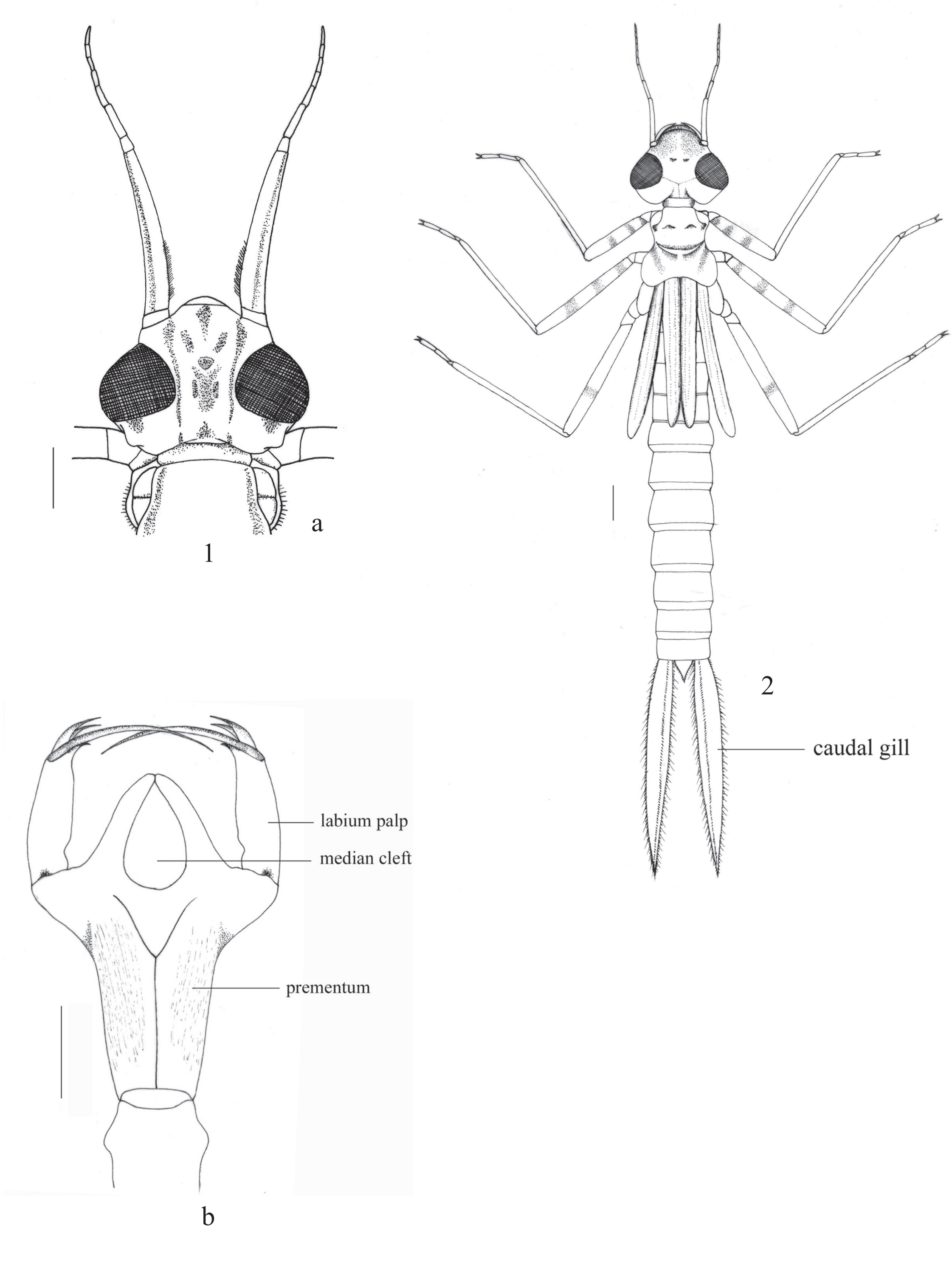


Fig. 1-2 1. Dorsal view of head (a) and labium (b) of Calopterygidae; 2. Dorsal view of nymph of Chlorocyphidae.
Scale = 1 mm.

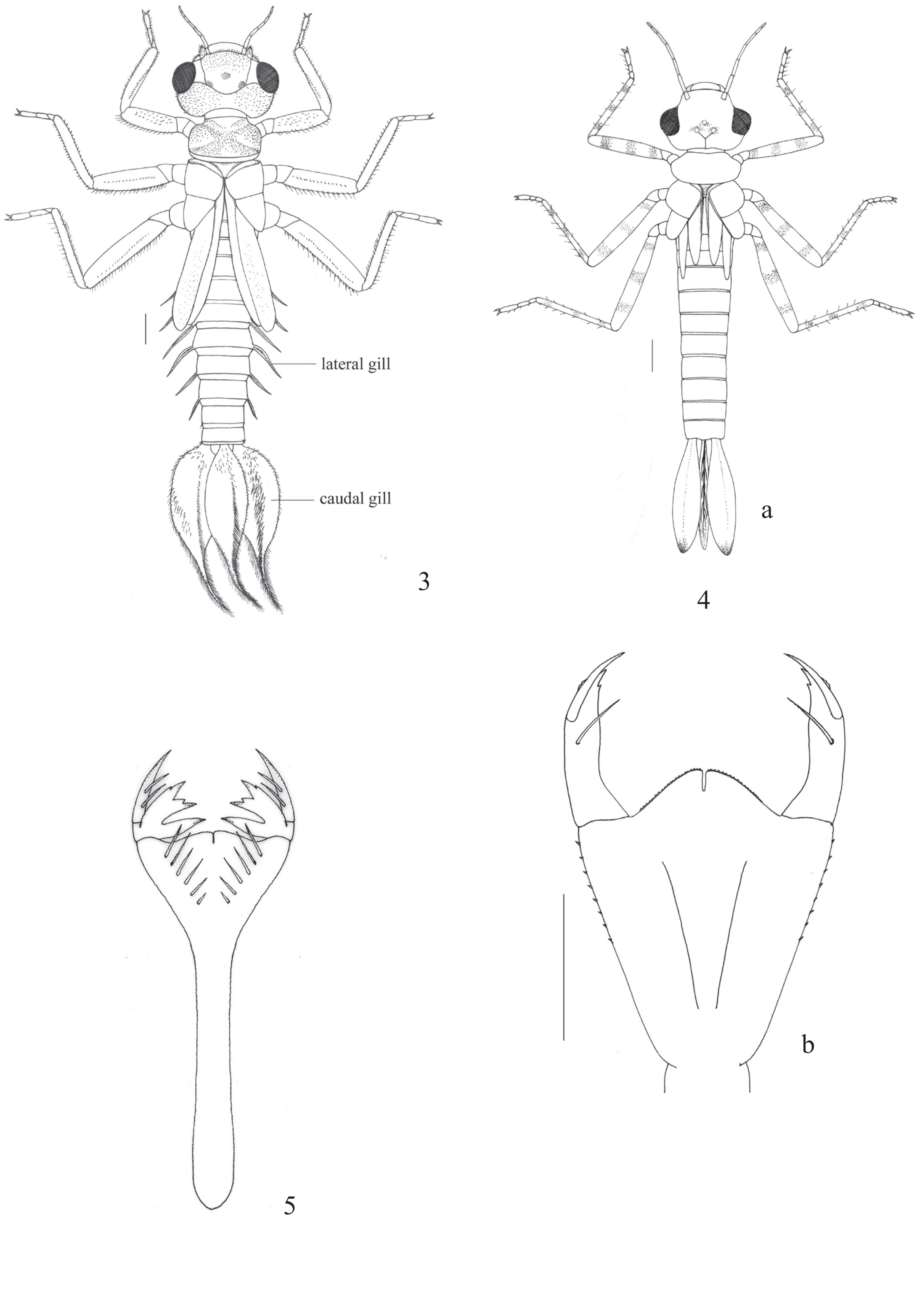


Fig. 3-5 3. Dorsal view of nymph of Euphaeidae; 4. Dorsal view (a) and labium (b) of nymph of Megapodagrionidae; 5. Labium of Lestidae (redrawn from Xiufu, 1998, fig. 11.148).
Scale = 1 mm.

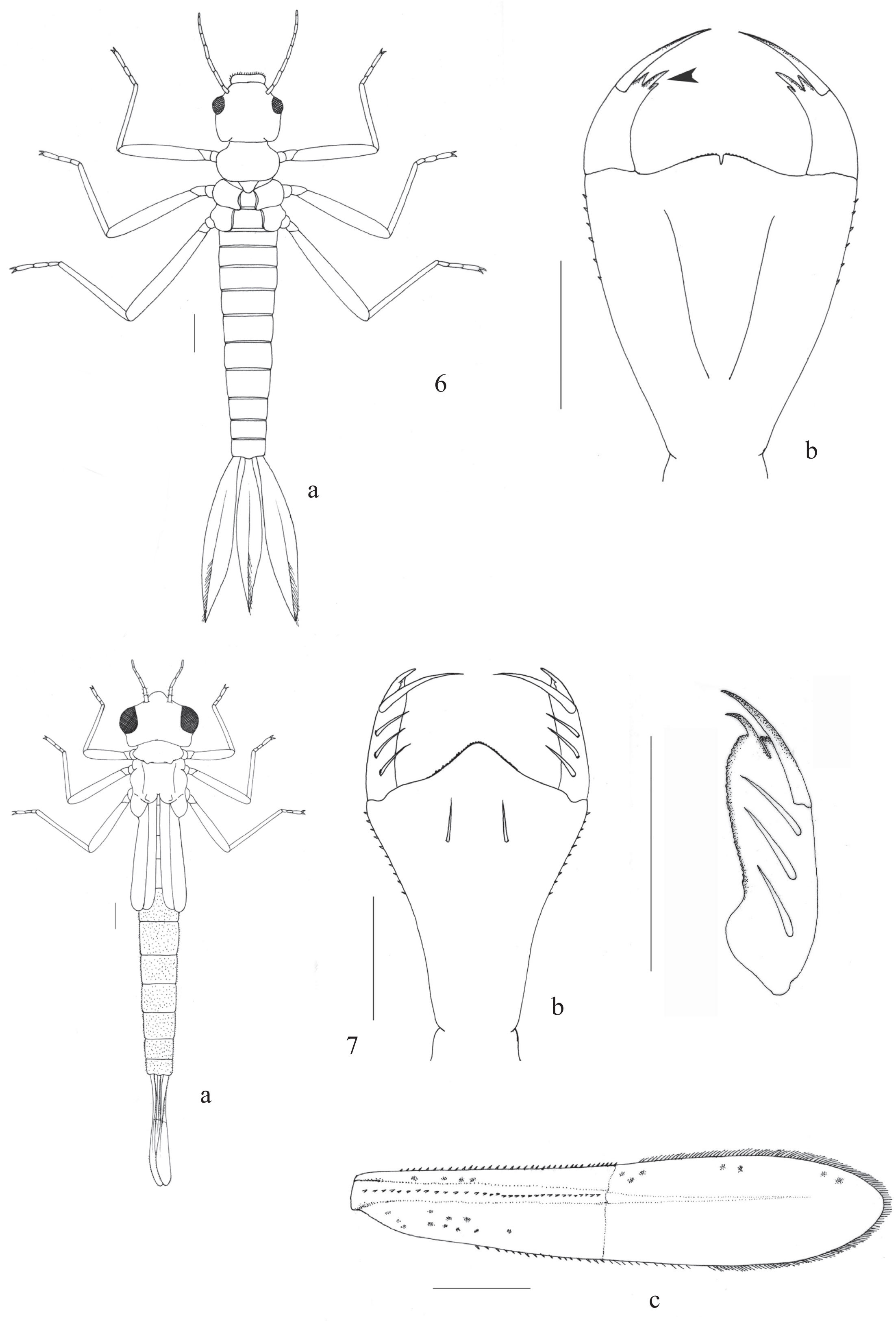


Fig. 6-7 6. Dorsal view of nymph (a) and labium (b) of Amphipterygidae; 7. Dorsal view of nymph (a), labium (b) and gill lamella (c) of Protoneuridae.
Scale = 1 mm.

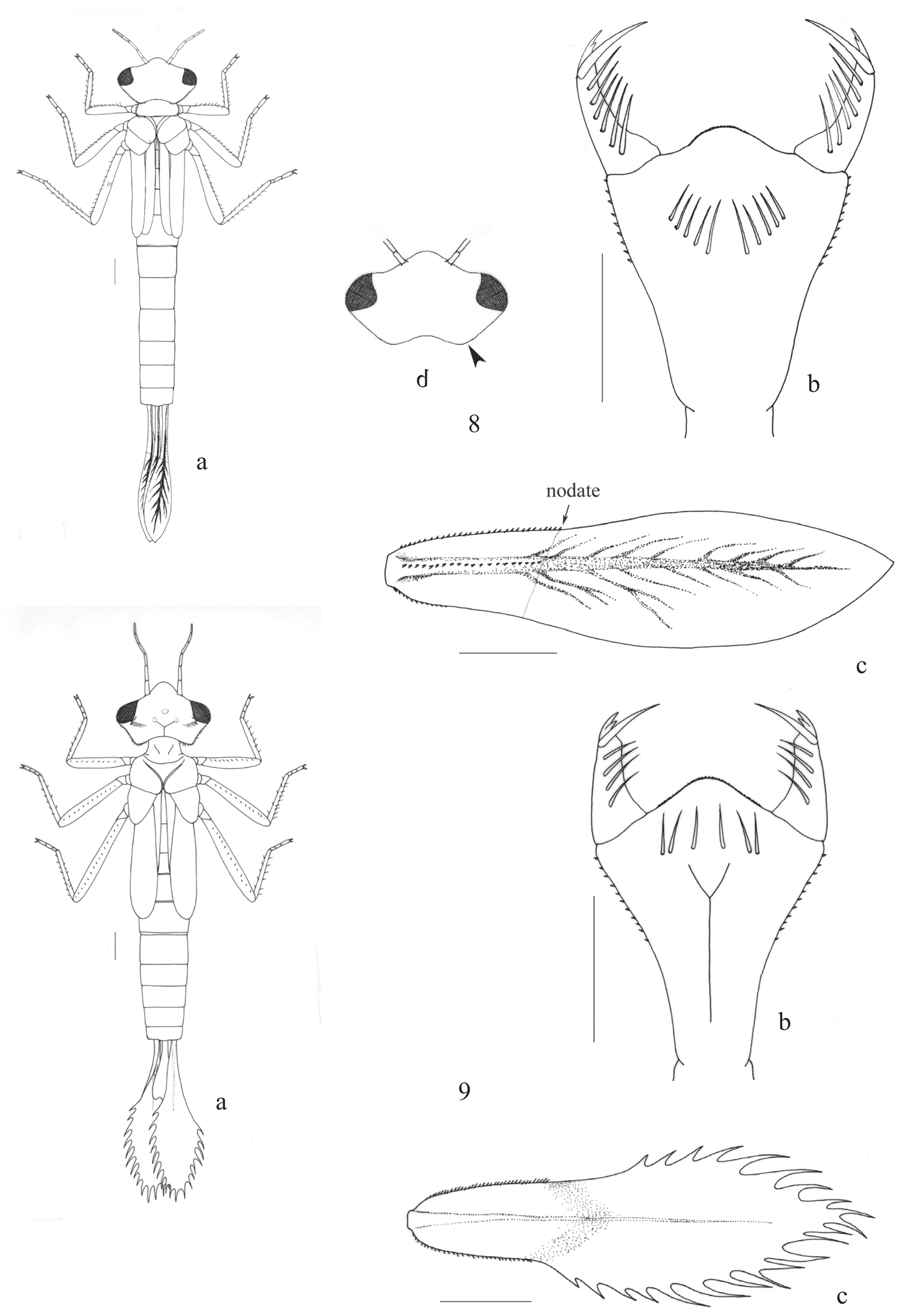
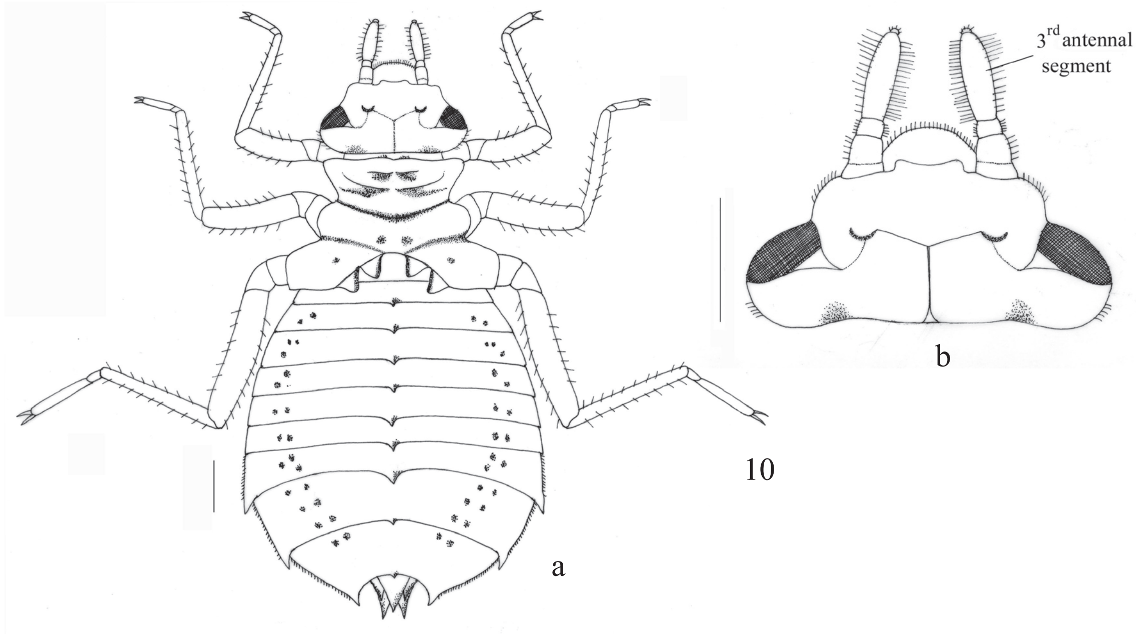


Fig. 8-9 8. Dorsal view of nymph (a), labium (b), gill lamella (c) and head (d) of Coenagrionidae; 9. Dorsal view of nymph (a), labium (b) and gill lamella (c) of some Platycnemidae.
Scale = 1 mm.



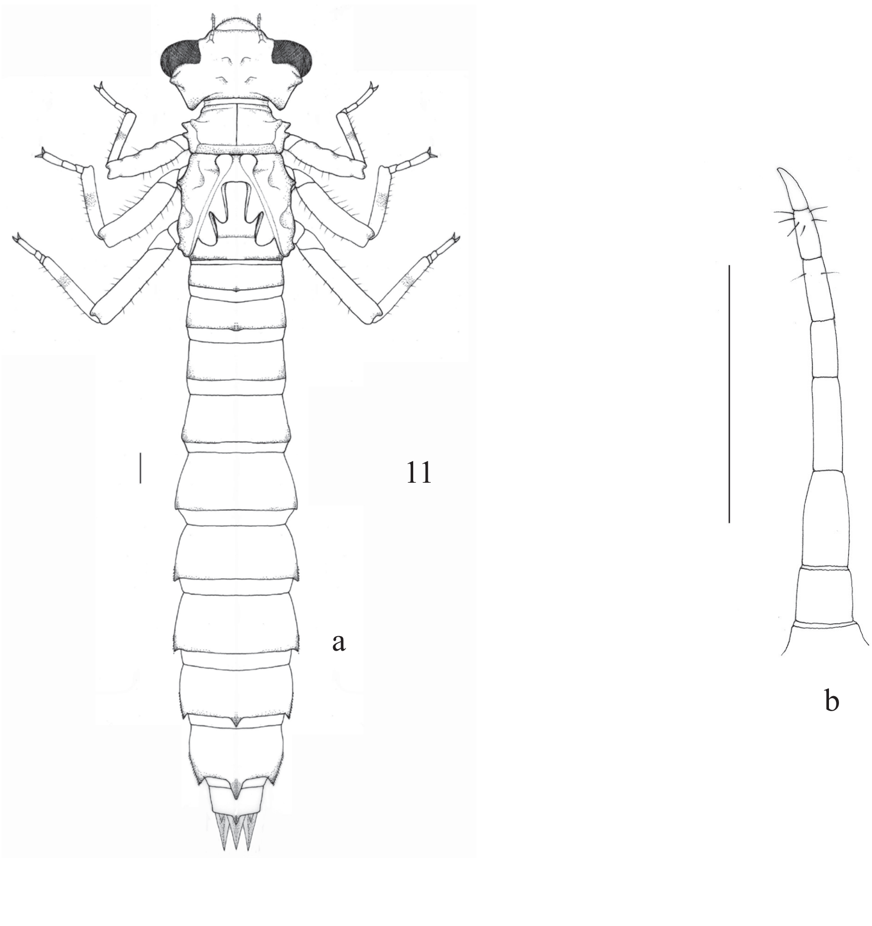
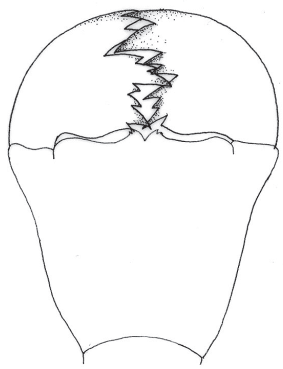


Fig. 10-11 10. Dorsal view of nymph (a) and head (b) of Gomphidae; 11. Dorsal view of nymph (a) and antennae (b) of Aeshnidae.
Scale = 1 mm.



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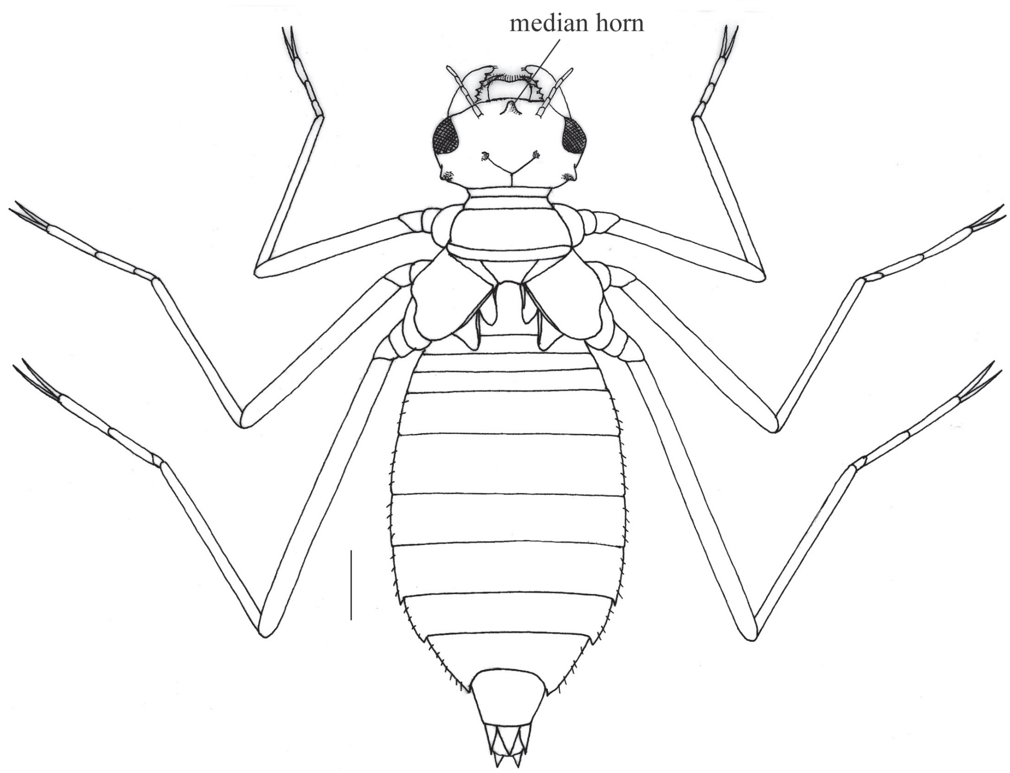

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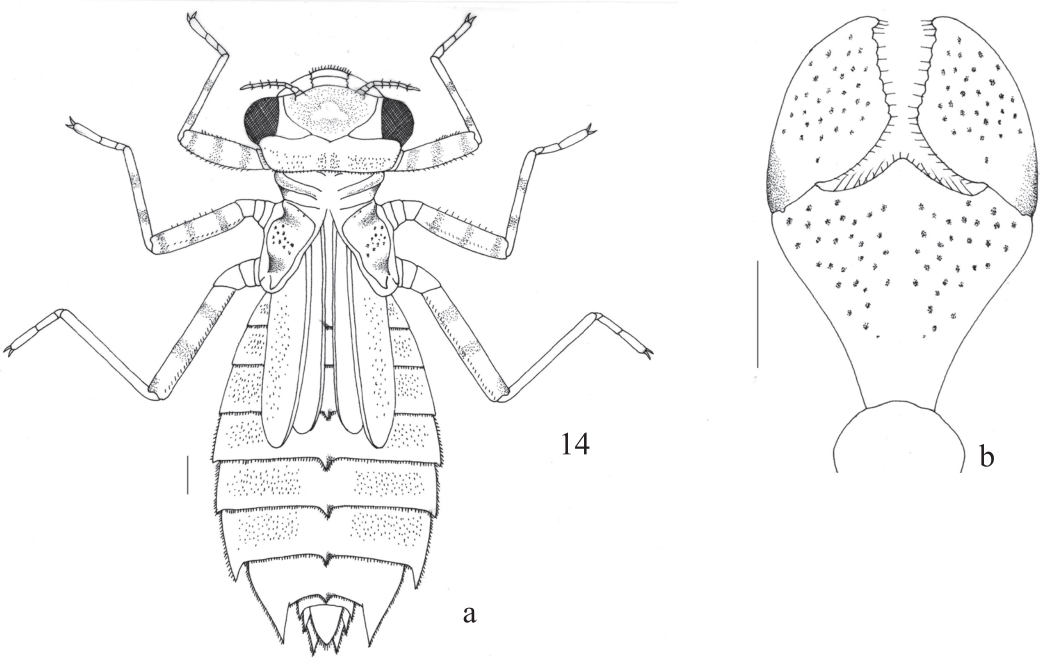
Fig. 12-13 12. Labium of Cordulegastridae (redrawn from Xiufu, 1998, fig. 11.85);
13. Dorsal view of nymph of Corduliidae (Macromiinae).
Scale = 1 mm.



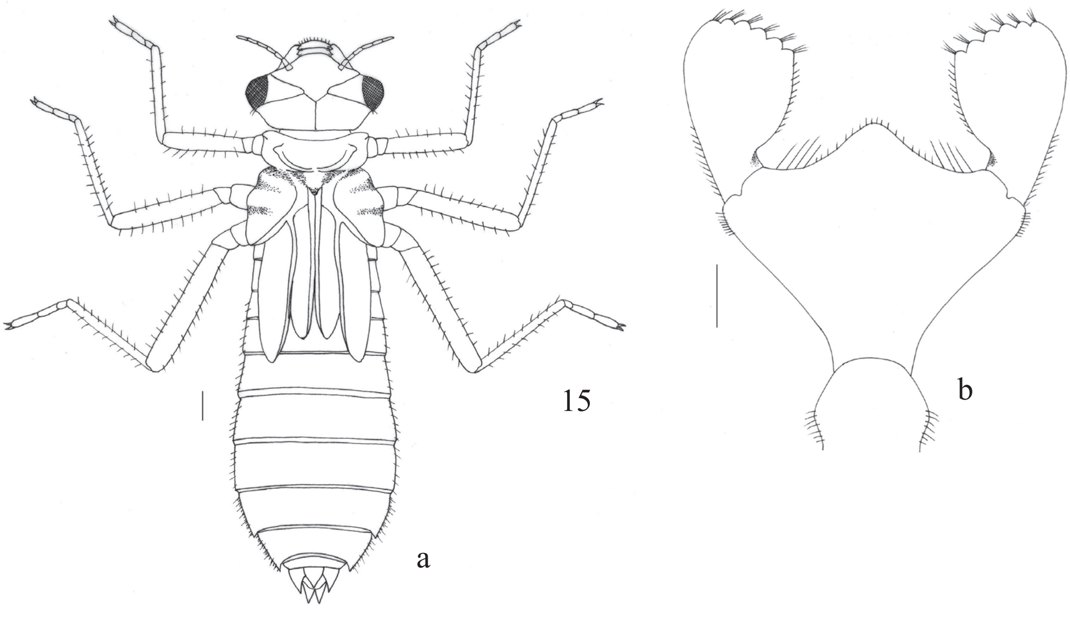


Fig. 14-15 14. Dorsal view of nymph (a) and labium (b) of Libellulidae; 15. Dorsal view of nymph (a) and labium (b) of Corduliidae (Corduliinae).
Scale = 1 mm.

Chapter 17 Order Orthoptera

Orthopterans live mainly in terrestrial environments, but some are hydrophilous are adapted to live along the margins of streams (Cantrall & Brusven, 1996). The semiaquatic orthopterans consist of grasshoppers, grouse locusts, pygmy mole crickets and mole crickets. Mole crickets (Gryllotalpidae) burrow into wet muddy soil along margin of freshwater habitats. Pygmy mole crickets (Tridactylidae) prefer to burrow into moist soil. Grouse locusts (Tetrigridae) usually sit on rocks along the margins of streams or in moist areas. Grasshoppers (Acrididae and Tettigoniidae) often occur in the paddy fields and grasslands.

Mole crickets bear front tibia modified for digging into muddy soil. The body is covered with short, fine setae to keep mud off the body. Grouse locusts have no special structures for swimming but they can jump off water very quickly if they fall onto its surface. Bishop (1973) noted that tridactylids might jump into water and burrow into the bottom sediments when they were disturbed. Field crickets (Gryllidae) burrow into shallow soil.

Little attention is given to this order, because most of Orthopterans have little economic importance. However, field crickets, *Gryllus bimaculatus*, are cultured for human consumption in Thailand. In this key Blaberidae is included in this order. This amphibious cockroach occurs in debris accumulations or beneath stones near aquatic habitats.

Key to Families of Adult Semiaquatic Orthoptera of Indochina

1 Body not cockroach-like 2
1′ Body dorsoventally flattened and cockroach-like (Fig. 1) .... Blaberidae

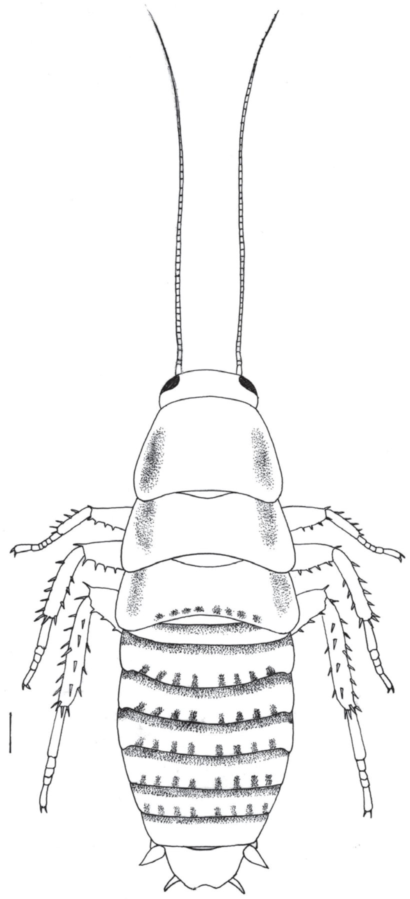
2(1) Front and middle tarsi 2 segmented 3
2′ Front and middle tarsi 3 or 4 segmented 4

3(2) Pronotum prolonged posteriorly to abdomen (Fig. 2) .... Tetrigidae
3′ Pronotum not prolonged posteriorly (Fig. 3) .... Tridactylidae

4(2′) All tarsi 3 segmented; antennae shorter or longer than body length 5
4′ All tarsi 4 segmented; antennae longer than body length (Fig. 4) .... Tettigoniidae

5(4) Front legs modified for digging; body covered with very short setae; antennae shorter than body length (Fig. 5) .... Gryllotalpidae
5′ Front legs similar to middle legs; body not covered with short setae; antennae shorter or longer than body length 6

6 (5′) Antenna shorter than body length (Fig. 6) .... Acrididae
6′ Antenna longer than body length .... Gryllidae



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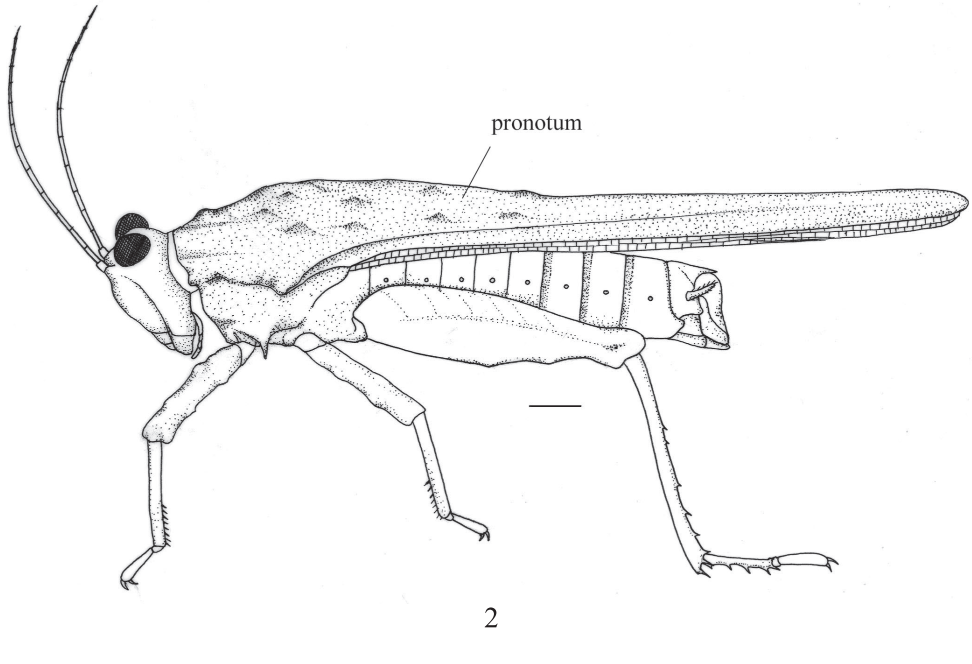

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Fig. 1-2 1. Dorsal view of Blaberidae; 2. Lateral view of pygmy mole cricket (Tetrigidae).
Scale = 1 mm.

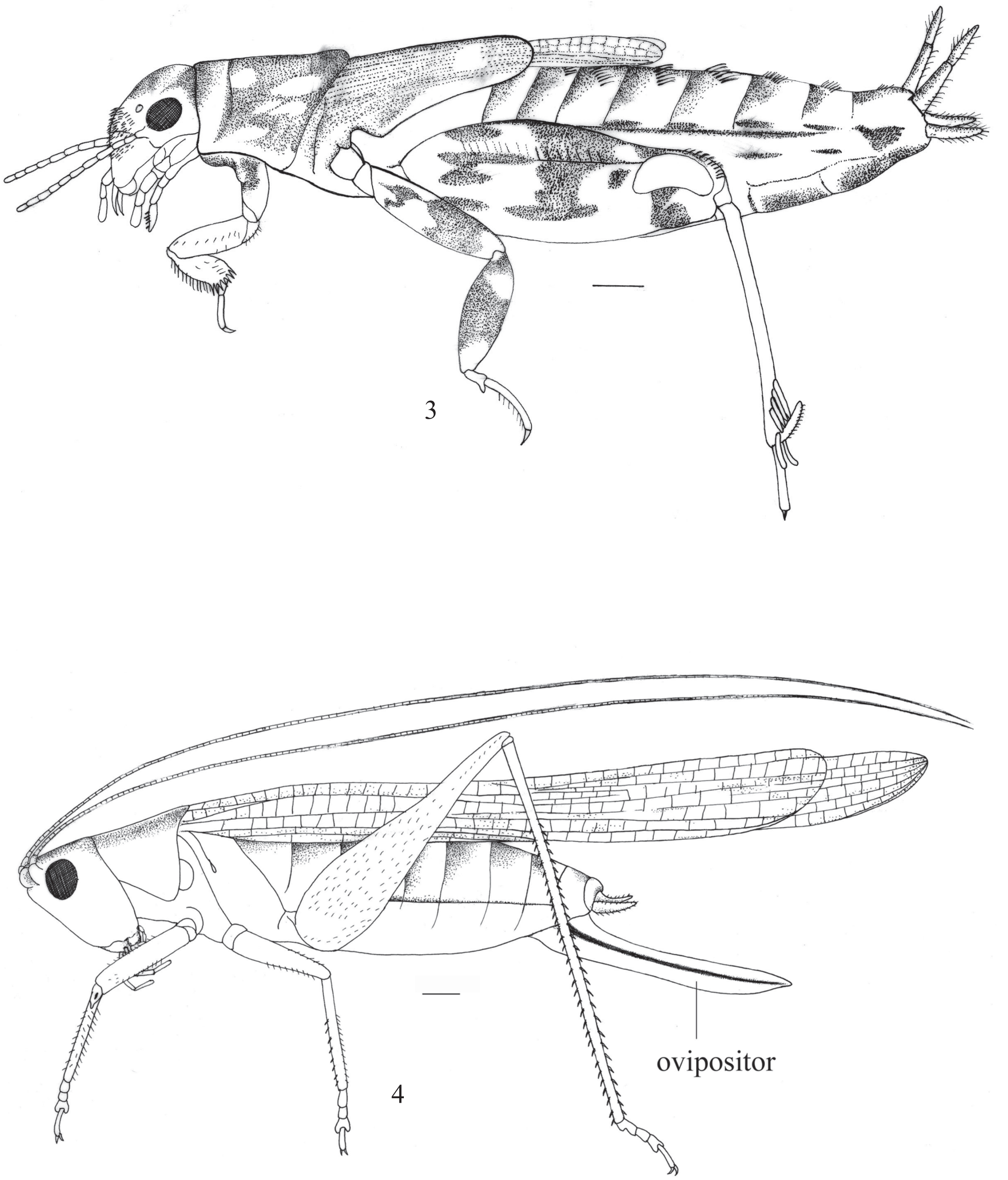
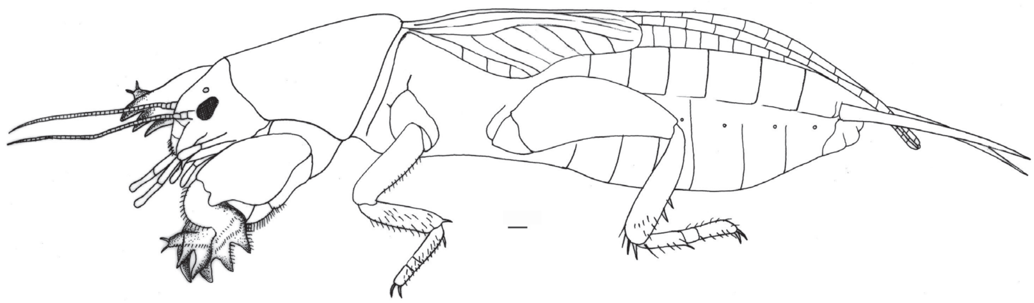


Fig 3-4 3. Lateral view of pygmy mole cricket (Tridactylidae); 4. Lateral view of female katydids (Tettigoniidae).
Scale = 1 mm.



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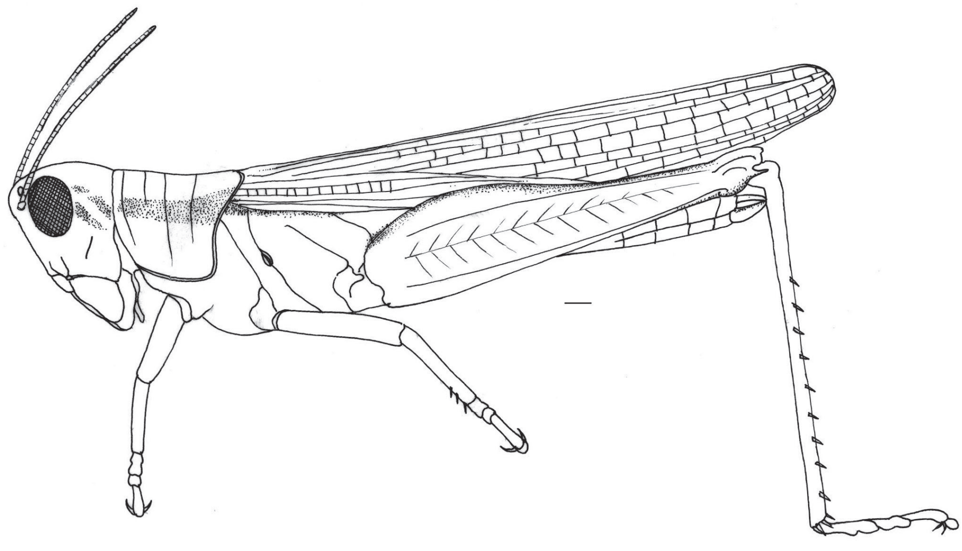

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Fig 5-6 5. Lateral view of mole cricket (Gryllotalpidae) 6. Lateral view of grasshoppers (Acrididae).
Scale = 1 mm.

Chapter 18 Order Plecoptera

The Plecoptera, or stoneflies, is one of the more ancient insect orders. It is more diverse in lotic habitats of temperate zones. Species richness decreases rapidly at the family level going from cool and temperate climates to warm and tropical ones (Zwick, 1986). Perlidae is the only diverse tropical family (Covich, 1988), and it is widespread from the north to Bali of Indonesia (Dudgeon, 1999).

Adults lay eggs attached to underwater rock surfaces in clean and cool stoney-bottomed streams. Nymphs either cling beneath rocks or in leaf packs, depending on their feeding habits. Nymphs of Peltoperlidae are shredders and restricted to headwater streams (Sangpradub, *et al.*, 1999). Most perlid nymphs are predators. Nymphs of *Etrocorema nigrogeniculatum* (Enderlein) eat aquatic insects—mainly chironomid and blackfly larvae (Chaisamsaeng, 2003). Adults and the exuvia of mature nymphs of Perlidae are often found on rock surfaces, but those of *Amphinemura* usually are found on debris accumulations or leaf packs near stream margins. Early instars may be found in the hyporheic zone (Klaythong, 1997).

Most of the literature on Asian Plecoptera involves the adult stage: Kawai (1969), Zwick (1982), Stark (1983), Sivec (1984), Zwick & Sivec (1985), Zwick (1986), Stark (1987), Sivec *et al.* (1988), Stark (1989), Stark & Sivec (1991), and Sivec & Zwick (1989). Among these, Sivec (1984) provides a key to adult *Neoperla* (Perlidae) of the Phillippines and Sivec *et al.* (1988) provides a key to the world genera of Perlinae adult and nymphs. A key to the families and genera of Indochina stonefly nymphs is provided here.

Key to Families and Genera of Mature Stonefly Nymphs (Plecoptera) of Indochina

1 Body cockroach-like; thorax much wider than head and abdomen (Fig. 1)............... ....Peltoperlidae...2

1′ Body not cockroach-like; thorax only slightly wider than rest of body 3

2(1) Posterior infracoxal gill absent ....*Cryptoperla*

2′ Posterior infracoxal gill on thoracic segments I-II single (Fig. 2)...... *Peltoperlopsis*

3(1′) Glossae of labium much shorter than paraglossae (Fig. 5b); mandibles elongate and slender; thorax with branched lateral gills..Perlidae...4

3′ Glossae of labium as long as paraglossae; mandibles short and stout (Fig. 13); no lateral gill on side of thorax segment I 11

4(3) Biocellate (2 ocelli) (Fig. 5a).. 5

4′ Triocellate (3 ocelli) (Fig. 9) 8

5(4) One pair of posterior supracoxal gills on thoracic segment III; posterior margin of mesosternum with setal fringe (Fig. 3) .... *Phanoperla*
5′ Two pairs of posterior supracoxal gills on thoracic segment III; posterior margin of mesosternum without setal fringe 6

6(5′) Occipital ridge with close-set complete row of short, thick setae (Fig. 4); body densely covered with black clothing setae .... *Tetropina*
6′ Occipital ridge at most a few short, thick setae laterally; clothing setae sparse, typically brown 7

7(6′) Lateral margin of pronotum completely fringed with thick setae (Fig. 5a); anal gills absent (Fig. 5c) .... *Etrocorema*
7′ Lateral margin of pronotum with fringe incomplete (Fig. 6a); anal gills typically present (Fig. 6b)... *Neoperla*

8(4′) Anal gills present (Fig. 6b) 9
8′ Anal gills absent 10

9(8) Posterior setae fringe of sternum segment VII incomplete (Fig. 7) .... *Paragnetina*
9′ Posterior setae fringe of sternum segment VII complete (Fig. 8)................*Agnetina*

10(8′) Thorax and abdomen without a median row of long silky setae .... *Togoperla*
10′ Thorax and abdomen with a median row of long silky setae (Fig. 9) .... *Kamimuria* or *Tyloperla*

11(3′) Body short; midline of metathoracic wing pads strongly divergent (Fig. 12a); cervical gills present or absent.. NEMOURIDAE...12
11′ Body elongate; midline of metathoracic wing pads parallel (Fig. 10); abdominal segments I-VII with membranous pleural fold................LEUCTRIDAE, *Rhopalopsole*

12(11) No cervical gills on the neck .... *Nemoura*
12′ Cervical gills present on the neck (Fig. 11,12,13,14)... 13

13(12′) Cervical gills reduced to stubbly or triangular projections (Fig. 11)....................... ....*Indonemoura*
13′ Cervical gills branched (Fig. 13,14) 14

14(13′) Cervical gills highly branched (Fig. 12b) .... *Amphinemura*
14′ Cervical gills consisting of four or six branches only 15

15(14′) Four cervical gills on the neck (Fig. 13) ....*Sphaeronemoura*
15′ Six cervical gills on the neck (Fig. 14) ....*Protonemura*

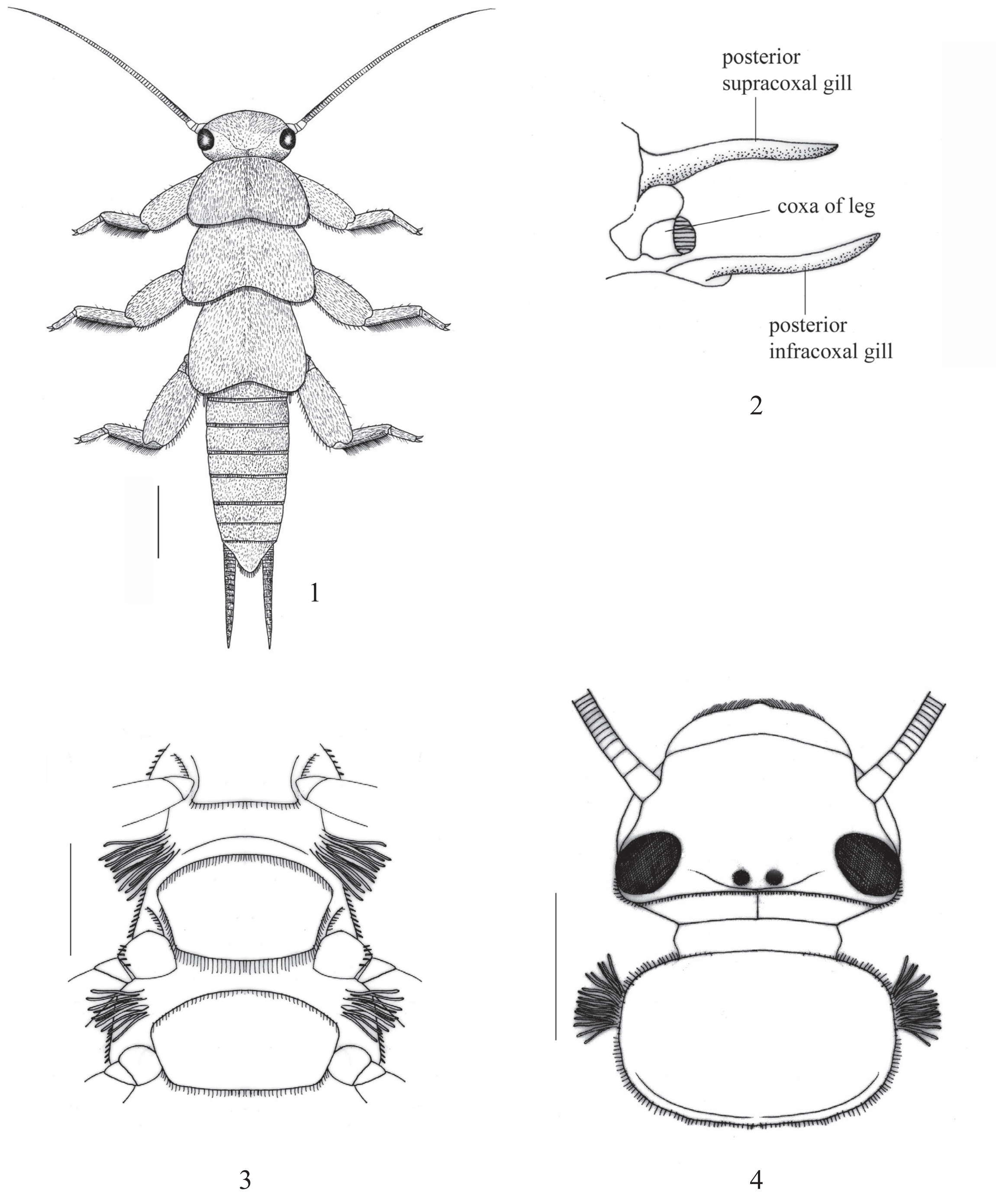


Fig. 1-4 1. Dorsal view of nymph of *Crytoperla* sp.; 2. Posterior infracoxal gill on thoracic segments I-II of *Peltoperlopsis* sp.(redrawn from Harper, 1994, fig. 12.48); 3. Ventral view of mesosternum of *Phanoperla* sp.; 4. Dorsal view of head and thorax of *Tetropina* sp.
Scale = 1 mm.

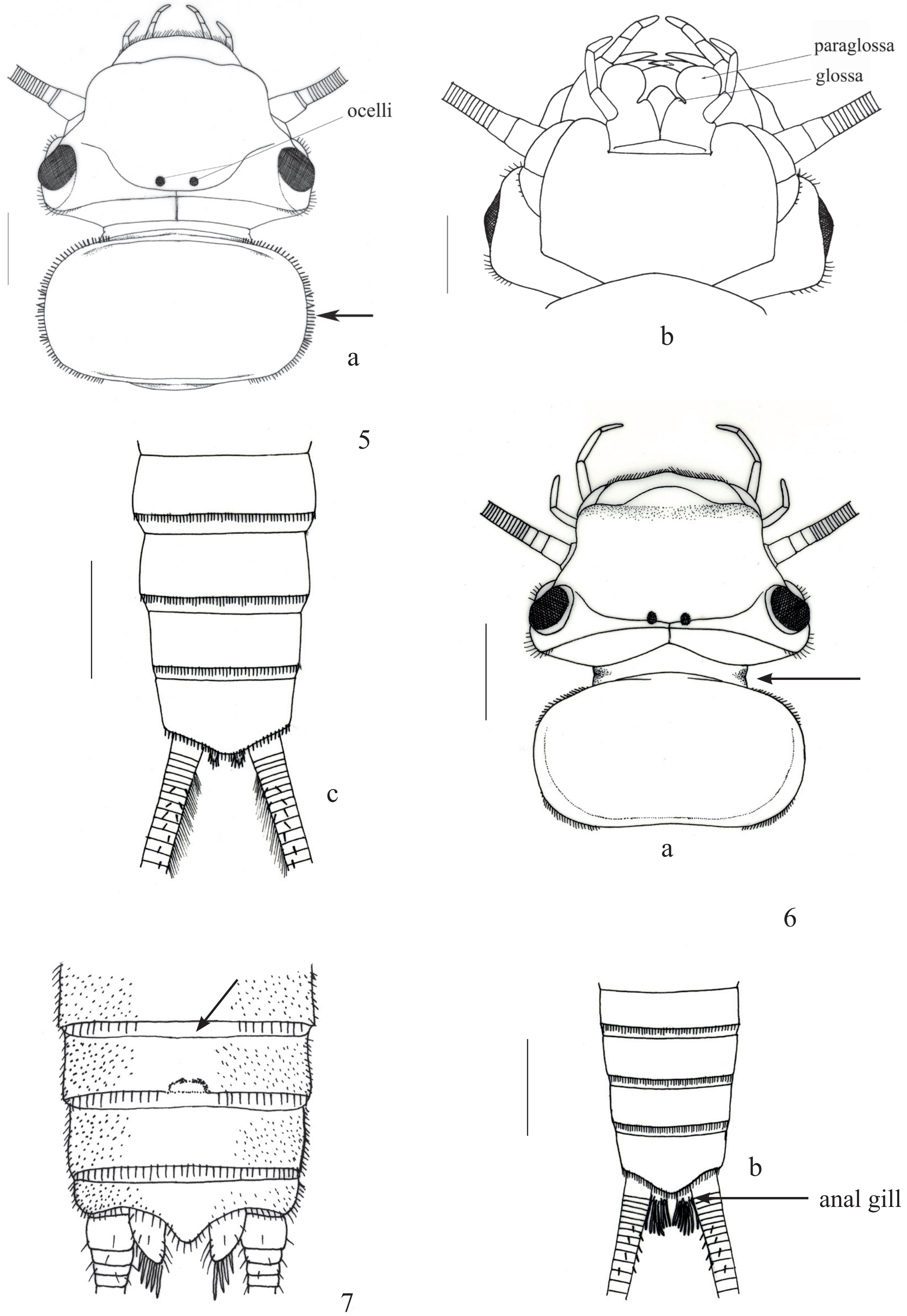
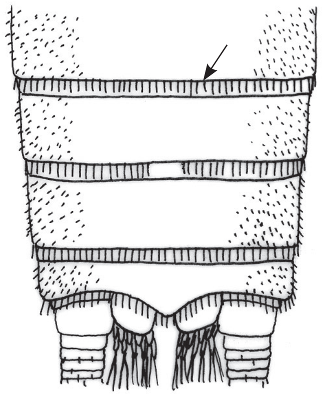


Fig. 5-7 5. Dorsal view of head and pronotum (a), ventral view of labium (b) and abdominal segments VII-X (c) of *Etrocorema* sp.; 6. Dorsal view of head and pronotum (a) and abdominal segments VII-X (b) of *Neoperla* sp.; 7. Sternum of abdominal segment VII of *Paragnetina* sp. (redrawn from Pescador et al., 2000, fig. 66).
Scale = 1 mm.



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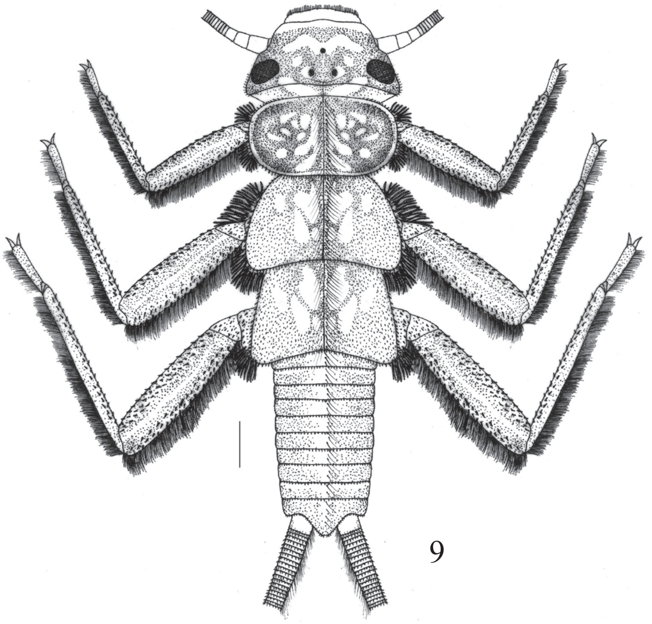

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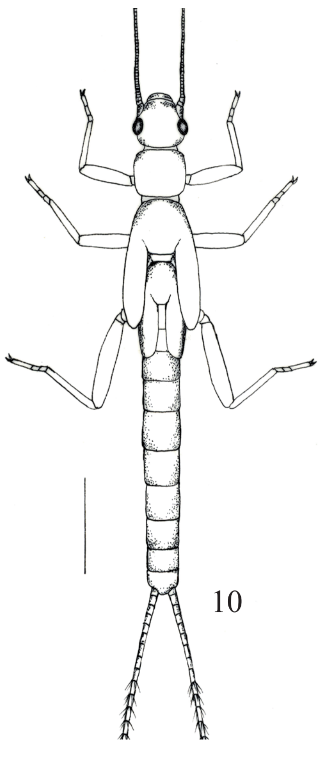

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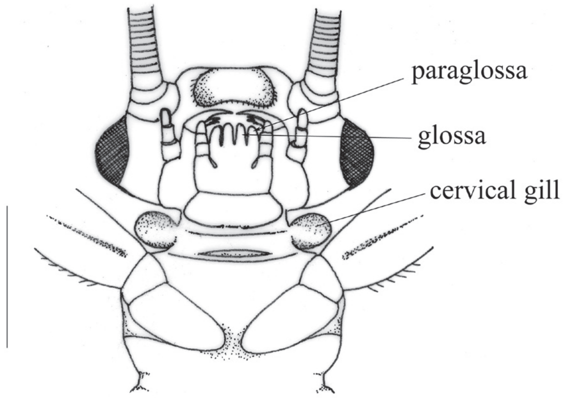

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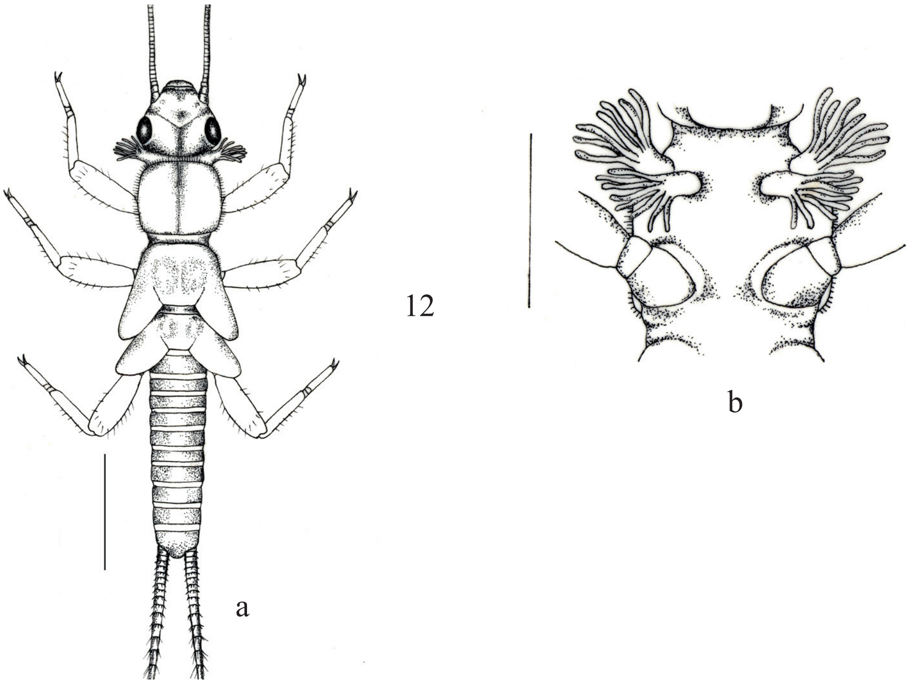
Fig. 8-10 8. Sternum of abdominal segment VII of *Agnetina* sp. (redrawn from Pescador et al., 2000, fig. 65); 9. Dorsal view of nymph of *Kamimuria* sp.; 10. Dorsal view of nymph of *Rhopalopsole* sp. 11. Ventral view of prothorax of *Indonemoura* sp.
Scale = 1 mm.



a

12

b

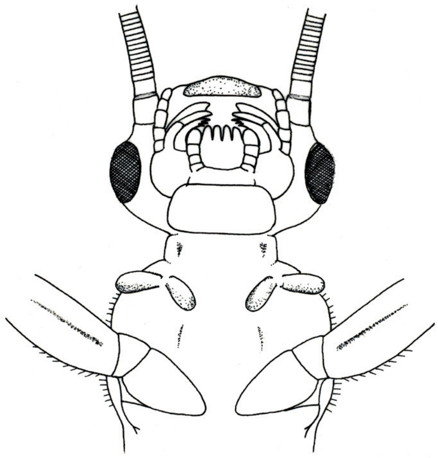


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Fig. 12-14 12. Dorsal view of nymph (a) and ventral view of cervical gills (b) of *Amphinemura* sp.; 13. Ventral view of head and prothorax of *Sphaeronemoura* sp.; 14. Ventral view of head and prothorax of *Protonemura* sp. (redrawn from Harper, 1994, fig. 12.41). Scale = 1 mm.

Chapter 19 Order Hemiptera

The Hemiptera, or true bugs, comprise two suborders, the Heteroptera and the Homoptera. All aquatic and semiaquatic bugs belong to the suborder Heteroptera which has three aquatic infraorders: Nepomorpha, Gerromorpha and Leptopodomorpha. They are widespread and occur in both freshwater and marine habitats.

Gerromorpha have the ability to move on the water's surface using unwettable hydrofuge pile on the tarsi, and sometimes on the tibia. When gerrid and veliid bugs retract the wettable claws, the unwettable hydrofuge pile allows them to glide over the water. Other Gerromorpha walk on the surface with a tripodal locomotion which involves alternating movements of opposite legs. Unlike Gerromorpha, Nepomorpha can swim in the water. Various water bugs have different air-store replenishment methods depending on the family, and naucorid bugs even have plastron respiration. Leptopodomorpha are semiaquatic bugs that live on the shore of water bodies.

Nymphs of Heteroptera resemble the adults but differ in body proportions, number of tarsal segments and the lack of wings. Wing pads occur in the last two instars. In Gerromorpha, nymphs have 1-segmented tarsi but adults have 1-3 segments. Gerridae, Helotrephidae, Hydrometridae, Naucoridae and Veliidae have polymorphism in wing development. Adults may have fully-developed wings (macropterous), short wings (brachypterous) or lack wings (apterous).

Aquatic and semiaquatic bugs include approximately 4,000 known species globally (Dudgeon, 1999). In the Indochina region there are about 43 genera of Gerromorpha and 21 genera of Nepomorpha. Publications on the aquatic and semiaquatic bugs of Indochina and Southeast Asian regions include: Lansbury (1968), Cheng & Fernando (1969), Bishop (1973), Polhemus & Polhemus (1988), Sites *et al.* (1997), Nieser (1998), Zettel (1998, 1999a and b), Sites and Polhemus (2000). The following keys are modified from Fernando & Cheng (1963), Cheng & Fernando (1969), Chen & Zettel (1996, 1998), Nieser (1996, 1998, 1999), Zettel & Chen (1996), Hecher (1998), Nieser & Polhemus (1998), Zettel (1998, 1999a and b), and Dudgeon (1999). They are based on adults but Nieser (1996) has stated that, except for size and wings, most characters are valid for nymphs too.

Key to Infraorders and Families of Adult Aquatic and Semiaquatic Heteroptera of Indochina

1 Antennae shorter than the head, inserted beneath the eyes and not visible from above........ infraorder Nepomorpha...2

1′ Antennae longer than the head, inserted in front of the eyes and visible from above 12

2(1) Ocelli present (Fig. 1,2)........ 3

2′ Ocelli absent 4

3(2) Tarsal formula 2-2-3; fore legs not conspicuously raptorial, fore femora not thickened (Fig. 1); rostrum very long and slender, reaching the hind coxae............. ....Ochteridae, *Ochterus*

3′ Tarsal formula 2-2-2; fore legs raptorial, fore femora strongly thickened (Fig. 2); rostrum short and stout, not reaching beyond the posterior margin of the prosternum .... Gelastocoridae, *Nerthra*

4(2′) Rostrum short and broadly triangular, non segmented (Fig. 45b)........................... 5

4′ Rostrum distinctly segmented and more or less parallel-sided 6

5(4) Scutellum exposed, rostrum without transverse grooves (Fig. 45a), small species, length less than 3 mm .... Micronectidae (p. 154)

5′ Scutellum entirely or nearly entirely covered by pronotum (Fig. 3), length 3 mm or more .... Corixidae, *Sigara (Tropocorixa)*

6(4′) Long and non-retractable posterior respiratory appendages present (Fig. 51-53)...... ....Nepidae (p. 154)

6′ Posterior respiratory appendages very short (Fig. 10,11)....................................... 7

7(6′) Respiratory appendages cylindrical, strip-like and retractable (Fig. 10, 11); membranes with distinct veins (Fig. 10) ....Belostomatidae (p. 150)

7′ Respiratory appendages absent; membranes without veins 8

8(7′) Fore legs raptorial; dorsoventrally flattened; head and prothorax not fused 9

8′ Fore legs not raptorial; dorsum usually convex or elongated............................... 10

9(8) Head usually longer than wide; rostrum long and slender, extending to hind coxae; fore femora slender (Fig. 7a) .... Aphelocheiridae, (p. 149) *Aphelocheirus*

9′ Head much wider than long; rostrum short and stout, not extending beyond fore coxae; fore femora broad (Fig. 46).. Naucoridae (p. 154)

10(8′) Head and pronotum fused (Fig. 38a, 39); antennae with 1 or 2 segments ....Helotrephidae (p. 153)

10′ Head and pronotum separate (Fig. 4a); antennae with 3 or 4 segments................ 11

11(10′) Body ovoid, small insects, length about 2.5 mm or Less, 4a), hind tarsus with 2 well-developed claws (Fig. 4b) .... Pleidae, *Paraplea*

11′ Body elongate (Fig. 55a), usually over 3 mm long, claws of hind tarsus inconspicuous .... Notonectidae (p. 155)

12(1′) Macropterous, brachypterous or apterous forms; hind coxae small; coxal cavities socket-like..INFRAORDER GERROMORPHA...13

12′ Macropterous; hind coxae large; coxal cavities broad .... INFRAORDER LEPTOPODOMORPHA...17

13(12) Head as long as or longer than thorax, eyes situated halfway along the head (Fig. 5) .... HYDROMETRIDAE, *Hydrometra*

13′ Head not distinctly prolonged; eyes situated at base of head (Fig. 6a, 33a, 36a)... 14

14(13′) Metanotal elevation distinctly exposed, forming a large plate (Fig. 33a), claws inserted apically (Fig. 33a,34a) 15

14′ Metanotal elevation not present, claws not inserted apically 16

15(14) Tarsi two-segmented (Fig. 32b), ventral surface of head with bucculae covering the base of rostrum (Fig. 33b) .... HEBRIDAE (p. 153)

15′ Tarsi three-segmented (Fig. 6b), bucculae absent (Fig. 6c)..................................... ....MESOVELIIDAE, *Mesovelia*

16(14′) Head medio-dorsally with a distinct impressed line (Fig. 65a), hind femora not longer than the abdomen; spacing between front and middle legs and between middle and hind legs is proximately equal length (Fig. 63a, 64a)............................. ....VELIIDAE (p. 156)

16′ Head medio-dorsally without an impressed line (Fig. 18c), hind femora much longer than the abdomen; spacing between front and middle legs is much greater than that between middle and hind legs (Fig. 12a, 13a, 16a, 18a) .... GERRIDAE (p. 150)

17(12′) Antennae never extend beyond the body; rostrum long, tapering, reaching base of hind coxae or beyond...SALDIIDAE (p. 155)

17′ Antennae longer than body; rostrum reaches to apex of fore coxae ....LEPTOPODIDAE (p. 154)

Family Aphelocheiridae—Key to Species of Aphelocheirus

1 Female with subgenital plate truncate (Fig. 7b); male with tab projecting from posterior margin of abdominal sternite V (Fig. 7c), not raised ....*Aphelocheirus grik*

1′ Female with subgenital plate triangular (Fig. 8,9); male with or without weakly developed tab on abdominal sternite V, if tab is present it is raised........................ 2

2(1′) Trochanter and base of femora in male with well-defined brown patch; peg-like setae on subgenital plate absent (Fig. 8)............................*Aphelocheirus femoratus*

2′ Trochanter and base of femora in male without brown patch; 4-6 peg-like setae present near apex of subgenital plate (Fig. 9).................. *Aphelocheirus malayanus*

Family Belostomatidae—Key to Genera of Belostomatidae

1 Hind tibia and tarsus strongly compressed, thin, much broader than the middle (Fig. 10); basal segment of rostrum about half the length of the second segment; body length over 5 cm .... *Lethocerus*

1′ Tibia and tarsus of middle and hind leg similar (Fig. 11); basal segment of rostrum longer than half of the second segment; body length less than 2 cm ....*Diplonychus*

Family Gerridae—Key to Genera of Gerridae

1 First abdominal sternite visible; tip of abdomen produced to a rod-like point (Fig. 12a,12c)...*Rhagadotarsus*

1′ First abdominal sternite not visible; tip of abdomen not produced to a rod-like point 2

2(1′) Middle femur shorter than middle tibia (Fig. 13) and usually shorter (except in *Cryptobates*) than hind femur... 3

2′ Middle femur longer than middle tibia and subequal or longer than hind femur (Fig. 16a,18a,21).. 5

3(2′) Third antennal segment much longer than the second 4

3′ Third antennal segment as long as or shorter than the second and distinctly shorter than the first (Fig. 13) ....*Naboandelus*

4(3) Head predominantly yellowish (Fig. 14); third antennal segment approximately twice as long as the second; fore femur of male straight........................*Cryptobates*

4′ Head predominantly blackish with yellow median stripe (Fig. 15); third antennal segment three times as long as the second; fore femur of male curved ....*Gnomobates*

5(2′) Body elongate, rarely stout (Fig. 16a, 18a, 21, 22, 25); metasternum well developed, clearly extending to the metacetabula laterally..................................... 6

5′ Body usually short, ovate or triangular (Fig. 29a, 30a, 31a); metasternum reduced.. 21

6(5) Metacetabular groove dorsally extending to anterior end of abdominal tergite I (Fig. 20a); fore tarsus at least 0.5 times as long as fore tibia (Fig. 16a,18a)............ 7

6′ Metacetabular groove not extending to anterior end of abdominal tergite I (Fig. 20b-c); fore tarsus less than 0.5 times as long as fore tibia (Fig. 21) 11

7(6) Large species, body length more than 15 mm; hind coxae with a small apical spine (Fig. 16b); hind femur much longer than mid femur; mid tibia of male with long fringe hairs (Fig. 16a) .... *Ptilomera*

7′ Small species, body length less than 10 mm; hind coxae without spine; hind femur subequal or shorter than middle femur; mid tibia without fringe of long hairs........ 8

8(7′) Dorsal appearance predominantly yellowish; antennal segment I shorter than next 3 segments combined (Fig. 17b); in dorsal view head anteriorly more rounded (Fig. 17a); male distinctly smaller than female .... *Rheumatogonus*

8′ Dorsal appearance predominantly blackish; antennal segment I distinctly longer or subequal to next 3 segments combined (Fig. 18a); in dorsal view head anteriorly with distinct corners at base of antennae (Fig. 18c); male slightly smaller than female 9

9(8′) Mesonotum with a yellow median line (Fig. 18a); fore femora ventrally with thin, hair-like bristles .... *Rhyacobates*

9′ Mesonotum medianly black; fore femora ventrally with thick bristles.................. 10

10(9′) Abdominal tergites I and II completely fused; female with hind coxae at least 3.5 times as long as wide; abdomen segment VI without processes .... *Andersenius*

10′ Abdominal tergites I and II separated (Fig. 19a); female with hind coxae slight longer than wide; abdomen segment VI with long spinous processes (Fig. 19b) .... *Pleciobates*

11(6′) Metacetabular groove distinct and extending to hind margin of the mesonotum (Fig. 20c); antennal segment IV short and curved; rostrum short, not extending beyond the posterior margin of prosternum; second fore tarsal segment more than twice as long as the first (Fig. 21); body very slender and cylindrical (Fig. 21) .... *Cylindrostethus*

11′ Metacetabular groove dorsally indistinct (Fig. 20b); antennal segment IV straight; rostrum longer, always extending beyond the posterior margin of prosternum; second fore tarsal segment less than twice as long as the first; body of different shape usually stouter and not cylindrical... 12

12(11′) Meso- and metacetabula with distinct patches of dense, silvery reflecting hairs; pronotum of apterous morph short, without pronotal lobe (Fig. 20c).................... 13

12′ Meso- and metacetabula with uniform hair layer; pronotum of apterous morph usually long, with well developed pronotal lobe (Fig. 20b).................................. 15

13 (12) Hind leg shorter than mid leg (Fig. 22) .... *Amemboa*
13′ Hind leg as long as mid leg 14

14(13′) Claws inserted at apex of tarsus; hind femur shorter than length of hind tibia and hind tarsus combined .... *Eotrechus*
14′ Claws inserted before apex of tarsus (Fig. 23); hind femur longer than hind tibia and hind tarsus together .... *Onychotrechus*

15(12′) Body large, length 30 mm and more .... *Gigantometra*
15′ Body smaller, length up to 20 mm... 16

16(15′) Pronotal lobe yellowish (Fig. 24); antenna as long as or longer than body (Fig. 25a) 17
16′ Pronotal lobe blackish (Fig. 27, 28); antenna shorter than body 18

17(16) Abdominal segment VI without spines; abdomen relatively short (Fig. 24)............ .... *Tenagogonus*
17′ Abdominal segment VI with long distinct spines (Fig. 25b); abdomen slender elongate (Fig. 25a) .... *Limnometra*

18(16′) Dorsal surface of head with black colour only... 19
18′ Dorsal surface of head with longitudinal or transverse yellowish on black colour.... 20

19(18) Antennal segment I longer than segments II and III together; body length 11 mm or more... *Aquarius*
19′ Antennal segment I shorter than segments II and III together (Fig. 26); body length 9 mm or less... *Gerris*

20(18′) Pronotal lobe with a central orange spot (Fig. 27) .... *Neogerris*
20′ Pronotal lobe with a yellow midline,or a pair of yellow spots, or both (Fig. 28) .... *Limnogonus*

21(5′) Eyes not extending beyond anterolateral angles of mesonotum (Fig. 29b)............... .... *Metrocoris*
21′ Eyes extending beyond anterolateral angles of mesonotum (Fig. 31b)................. 22

22(21′) Anterior portion of thorax as wide as metanotum: antennal segment III of male enlarged and with a fringe of stiff hairs along margin (Fig. 30b).................. *Esakia*
22′ Anterior portion of thorax distinctly narrowed (Fig. 31a); antennal segment III of male not modified (Fig. 31c) .... *Ventidius*

Family Hebridae—Key to Genera of Hebridae

1 Head short and broad; slender femora (Fig. 34a, 36a) 3
1′ Head long, narrow and pointed (Fig. 33a); stout femora (Fig. 33b)........................ 2

2(1′) Antennal segment I shorter than segments II and IV (Fig. 32a); head below eyes without conspicuous long bristles, only with some relatively short hairs; legs slender (Fig. 32b)... *Nieserius*
2′ Antennal segment I longer than segments II and subequal to segment IV (Fig. 33b); head below eyes with a tuft of conspicuous long bristles; legs stout ....*Hyrcanus*

3(1) Antennae 5-segmented (Fig. 35a, 36b), last segment divided by a desclerotized zone.. 4
3′ Antennae 4-segmented (Fig. 34), desclerotized zone absent....................*Merragata*

4(3) Paired, longitudinal carinae of thoracic venter converging and meeting before hind margin of metasternum (Fig. 35b) ....*Timasius*
4′ Paired, longitudinal carinae of thoracic venter parallel throughout and continuing separately onto the base of abdomen (Fig. 36c) .... *Hebrus*

Family Helotrephidae—Key to Genera of Helotrephidae

1 Tarsal formula 3-3-3 (Fig. 37a-b); body depressed .... *Fischerotrephes*
1′ Tarsal formula 2-2-3 or 1-1-2, body usually globular 2

2(1′) Tarsal formula 2-2-3 (Fig. 38b); hemelytron with pseudendocorium (Fig. 38a)........ .... *Trephotomas*
2′ Tarsal formula 1-1-2; hemelytron without pseudendocorium 3

3(2′) Cephalonotum dull, with densely punctuate; postero-lateral margin of cephalonotum continued under the eye 4
3′ Cephalonotum shining; postero-lateral margin of cephalonotum not continued under the eye.. 5

4(3) Abdominal sternite IV (or IV and V) with median keel ....*Helotrephes*
4′ Abdominal sternite IV and V without median keel .... *Hydrotrephes*

5(3′) Eyes divided into dorsal and ventral part (Fig. 39a); female subgenital plate with asymmetrical middle lobe (Fig. 39b)..*Distotrephes*
5′ Eyes indented (Fig. 41a); female subgenital plate with one or two incisions (Fig. 40b) 6

6(5′) Lateral margin of cephalonotum not extending onto eye surface, only indistinctly indenting the eye at posterior margin (Fig. 40a).................................. *Tiphotrephes*
6′ Lateral margin of cephalonotum clearly extending onto eye surface, deeply indenting the eye (Fig. 41a) 7

7(6′) Female subgenital plate asymmetrical (Fig. 41b) or with less deep dextrocaudal incision and usually with distinct dextrocaudal break............................ *Idiotrephes*
7′ Female subgenital plate subsymmetrical, simple, without incision or break .... *Limnotrephes*

Family Leptopodidae—Key to Genera of Leptopodidae

1 Eyes dorsally chitinous, opaque and nonfunctional (Fig. 42) ....*Leotichius*
1′ Eyes dorsally normal, set with ommatidia, unctional... 2

2(1′) Head, pronotum, and hemelytral margins spinose (Fig. 43)..................................... ....*Patapius* (*Pseudopatapius)*
2′ Head, pronotum, and hemelytral margins non-spinose (Fig. 44) .... *Valleriola*

Family Micronectidae—Key to Genera of Micronectidae

1 Vertex with an impression; fore tibia and tarsus of male fused............*Synaptonecta*
1′ Vertex convex (rarely flattened); fore tibia and tarsus of male separated (Fig. 45a). ....*Micronecta*

Family Naucoridae Key to Genera of Naucoridae

1 Front leg with one-segmented tarsus and a single claw (Fig. 46) ....*Naucoris*
1′ Front leg with two-segmented tarsus and two claw (Fig. 47a)............................... 2

2(1′) Venter of metatibia with subapical spines arranged in two or more parallel rows (Fig. 47b) ....*Heleocoris*
2′ Venter of metatibia not as above.................................. *Ctenipocoris* or *Laccocoris*

Family Nepidae—Key to Genera of Nepidae

1 Body dorso-ventrally flattened; parasternites visible (Fig. 48a)........... Nepinae…..2
1′ Body more or less cylindrical; parasternites concealed by the ventral laterotergites (Fig. 49a-b) ....Ranatrinae……4

2(1) Venter of pronotum with spiracular apertures (Fig. 50); siphon as long as half the length of the inner margin of hemelytra ....*Telmatotrephes*
2′ Ventral spiracular apertures on pronotum vestigial or absent, siphon more than two thirds the length of inner margin of hemelytra 3

3(2′) Membrane of hemelytra and corium different; siphon longer than inner margin of hemelytra (Fig. 51) .... *Laccotrephes*

3′ Membrane of hemelytra not different from corium, siphon shorter than inner margin of hemelytra.. *Borborophyes*

4(1′) Siphon short and rigid; fore femora shorter than pronotum **(**Fig. 52) .... *Cercotmetus*

4′ Siphon long and flexible; fore femora as long as or longer than pronotum (Fig. 53) .... *Ranatra*

Family Notonectidae—Key to Genera of Notonectidae

1 With a seta-lined pit at anterior end of hemelytral commissure (Fig. 55a) 2

1′ Without a seta-lined pit at anterior end of hemelytral commissure........................ 4

2(1) Hind coxal plate covered with long black setae (Fig. 54) .... *Paranisops*

2′ Hind coxal plate not covered with long black setae (Fig. 55b) 3

3(2) Antennae three-segmented; rostrum of male with a prominent lateral prong (Fig. 55c), fore tibia with stridular pegs packed closely together and situated on a protuberance (Fig. 55d) .... *Anisops*

3′ Antennae two-segmented; rostrum of male without a prominent lateral prong, fore tibia without stridular pegs packed closely together and situated on a protuberance (Fig. 56) .... *Walambianisops*

4(1′) Anterolateral margins of prothorax foveate (Fig. 57a,58,59)................................. 5

4′ Anterolateral margins of prothorax not foveate....................................... *Notonecta*

5(4) Middle femora with an ante-apical pointed protuberance (Fig. 57a-b)....... *Enithares*

5′ Middle femora without an ante-apical pointed protuberance 6

6(5′) Basal half of eyes meet in the middle (Fig. 58).. *Nychia*

6′ Eyes widely separated at base (Fig. 59) .... *Aphelonecta*

Family Saldidae—Key to Genera of Saldidae

1 Hemelytral membrane with five large parallel cells (Fig. 60).................. *Pentacora*

1′ Hemelytral membrane with four large parallel cells 2

2(1′) Anterior margin of pronotum strongly narrowed (Fig. 61a), with a pair of dorsal outgrowths (Fig. 61b)... *Saldoida*

2′ Anterior margin of pronotum not strongly narrowed, without outgrowths (Fig. 62) .... *Saldula*, and *Micracanthia*

Family Veliidae—Key to genera of Veliidae

1 Mid-tarsi with three segments (basal segment sometimes very short) 2

1′ Mid-tarsi with two segments 7

2(1) Tarsal formula 2-3-3, basal segment of fore tarsi very short; first segment of mid-tarsi subequal in length to segment I and III together; fore wings divided into proximal coriaceous part with two closed cells and distal membranous part (Fig. 63b); bright orange or reddish coloured .... *Perittopus*

2′ Tarsal formula 3-3-3, basal segment of fore and hind tarsi sometimes very short; fore wings not as above, with four closed cells (Fig. 66a); blackish or yellowish brown coloured 3

3(2′) Mid-tarsi deeply cleft, with leaf-like claws and plumose swimming fans arising from base of cleft, which are folded up at rest (Fig. 64b) 4

3′ Mid- tarsi not deeply cleft, without plumose swimming fans 6

4(3) Hind tarsi deeply cleft, with swimming fans; pronotum long .... *Rhagovelia*

4′ Hind tarsi not cleft and without swimming fan; pronotum short (Fig. 64a)............ 5

5(4) Stridulatory devices present on connexival margin of sternites II and III (Fig. 65b) and on hind femur (Fig. 65c); anterior margin of pronotum laterally with a narrow and deep incision (Fig. 65d) .... *Chenevelia*

5′ Stridulatory devices absent; anterior margin of pronotum with indistinct or no incision ....*Tetraripis*

6(3′) Apical part of fore wing with one large, irregular white spot surrounded by 2-4 small spots (Fig. 66a); head distinctly deflected in front of eyes (Fig. 66b); fore tibia with long grasping comb in both male and female............................... *Angilia*

6′ Macropterous morph with apex of pronotum without finger-like projection; head moderately deflected in front of eyes; only fore tibia in male with grasping comb ... .*Angilovelia*

7(1′) Tarsal formula 2-2-2 (basal segment of fore tarsi very short); middle leg obviously longer than hind leg; mid-tarsal length three or more times as long as hind tarsi.... 8

7′ Tarsal formula 1-2-2; middle leg subequal to hind leg; mid-tarsal length rarely more than twice as long as hind tarsi... 9

8(7) Second segment of antenna longer than or subequal to the first (Fig. 67b); hind tarsal segments subequal in length (Fig. 67c); body with yellow markings, but without dense pilosity (Fig. 67a) .... *Strongylovelia*

8′ Second segment of antenna shorter than the first (Fig. 68a); first hind tarsal segment about half as long as second segment (Fig. 68b); body without yellow markings, but with dense pilosity .... *Entomovelia*

9(7′) Head posteriorly produced, extending well behind margin of eyes, anterior margin of pronotum notched; elongated and relative slender body 10

9′ Head not produced; anterior margin of pronotum straight or slightly convex (Fig. 69,70); relatively short and stout body 11

10(9) Male fore tibia with grasping comb; femora usually modified on posterior margin . ... *Neoalardus*

10′ Male fore tibia without grasping comb; femora simple 12

11(9′) Eyes not close to anterior margin of pronotum (Fig. 69)........................ *Lathriovelia*

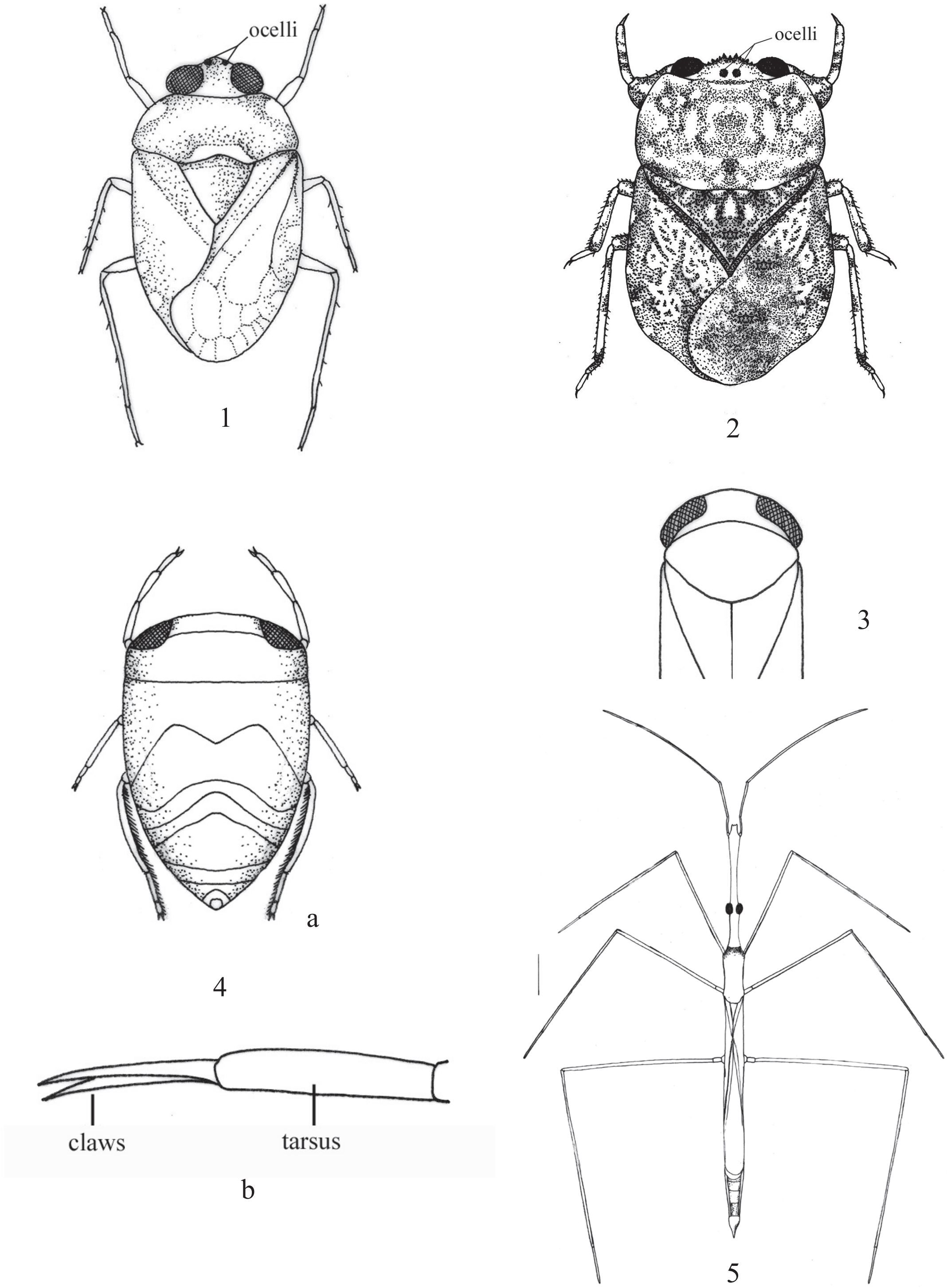
11′ Eyes close to anterior margin of pronotum (Fig. 70).................................... *Baptista*

12(10′) Antennal segment I incrassate (Fig. 71b); in macropterous morph apical cells of fore wings reduced (Fig. 71a); in apterous morph pronotal lobe long.....*Pseudovelia*

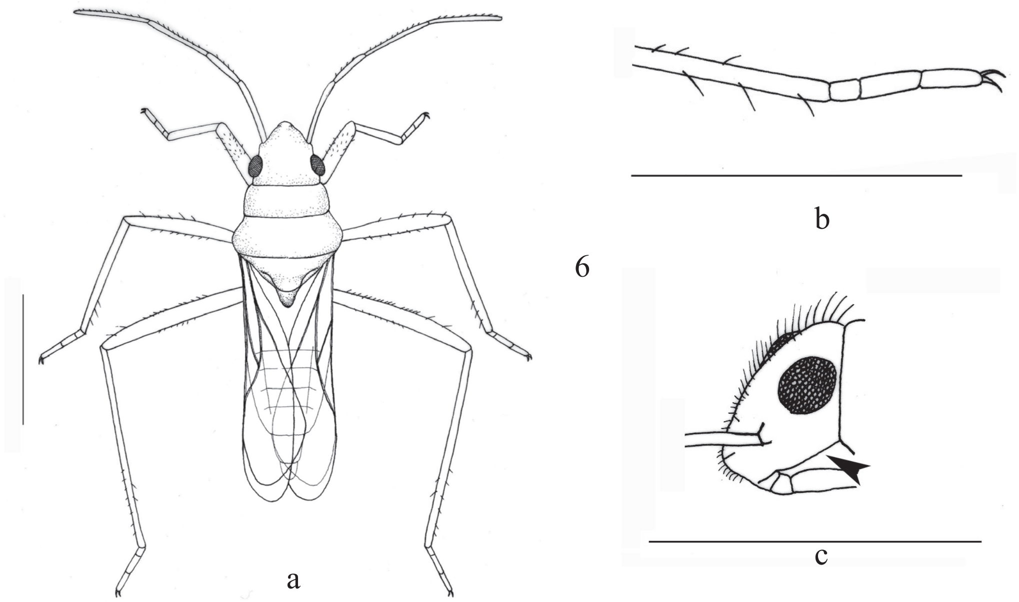
12′ Antennal segment I slender and much shorter; macropterous morph with fore wing venation normal (Fig. 73a) 13

13(12′) .Mid-tarsi with arolium and ventral claws (Fig. 72b); pronotum of apterous morph short (Fig. 72)..*Xiphovelia*

13′ Mid-tarsi normal (Fig. 73b); pronotum of apterous morph long (Fig. 73a) ....*Microvelia*



Figs. 1-5 1. Dorsal view of *Ochterus* sp. (Ochteridae) (redrawn from Nieser, 1996, fig. 3); 2. Dorsal view of *Nerthra* sp. (Gelastocoridae) (redrawn from Nieser, 1996, fig. 4); 3. Dorsal view of *Sigara* sp. (redrawn from Fernando & Cheng, 1963, fig. 73); 4. Dorsal view (a) and hind tarsus (b) of *Paraplea* sp. (redrawn from Dudgeon, 1999, fig. 4.77A); 5. Dorsal view of *Hydrometra* sp.
Scale = 1 mm.



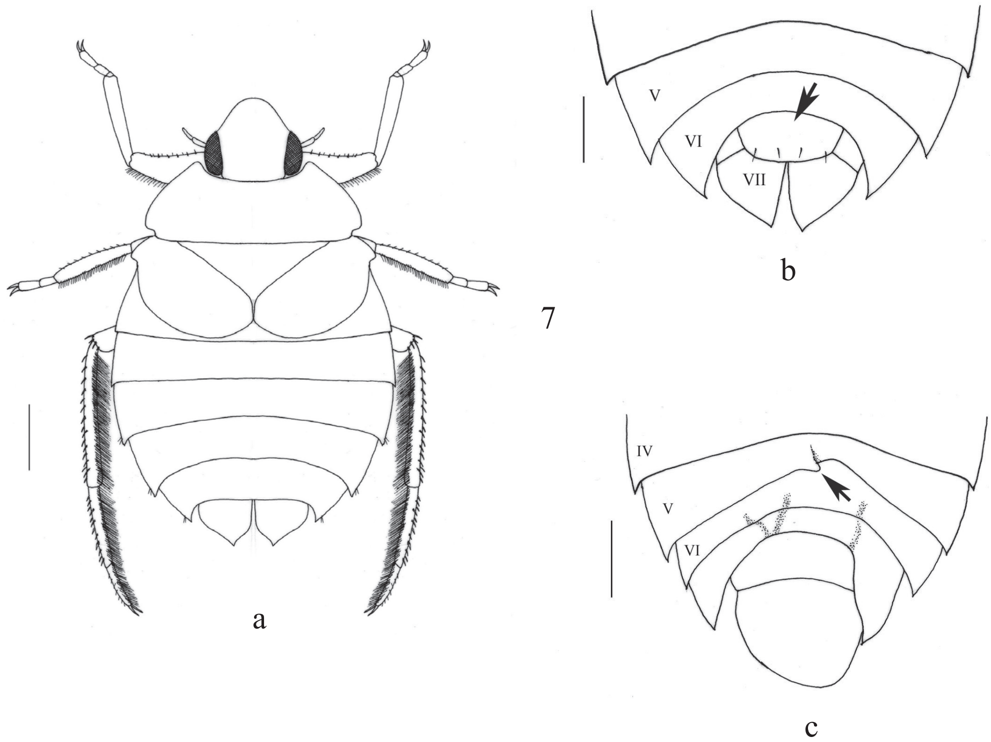
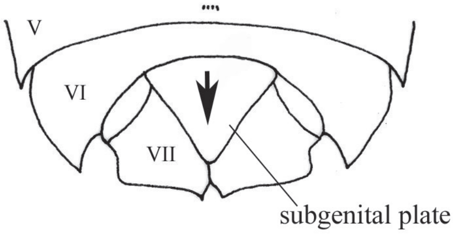


Fig. 6-7 6. Dorsal view of adult (a), hind tarsi (b) and lateral head (c) of *Mesovelia* sp.;
7. Dorsal view of brachypterous female (a), subgenital plate of female (b) and abdominal sternite V of male (c) of *Aphelocheirus grik*.
Scale = 1 mm.



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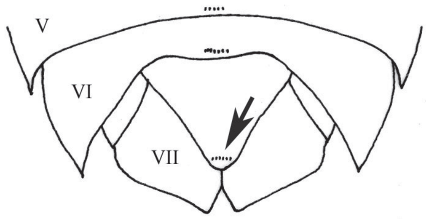

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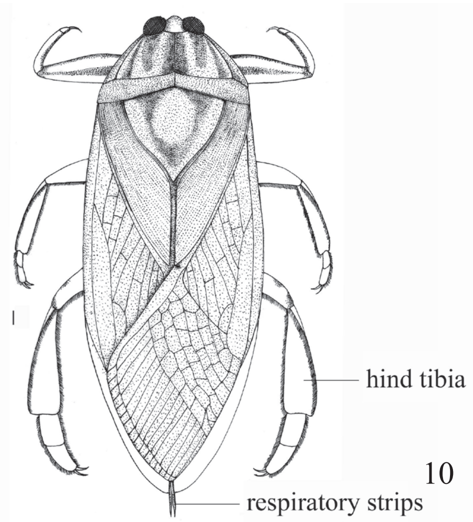

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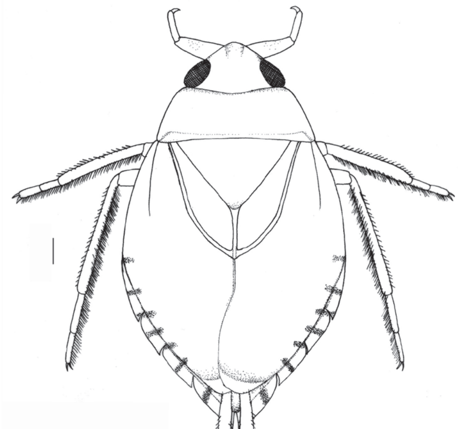

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Fig. 8-11 8. Subgenital plate of female of *Aphelocheirus femorantus* (redrawn from Sites *et al*., 1997, fig. 5); 9. Subgenital plate of female of *Aphelocheirus malayanus* (redrawn from Sites *et al*., 1997, fig. 6); 10. Dorsal view of adult of *Lethocerus indicus*; 11. Dorsal view of adult of *Diplonychus rusticus*.
Scale = 1 mm.

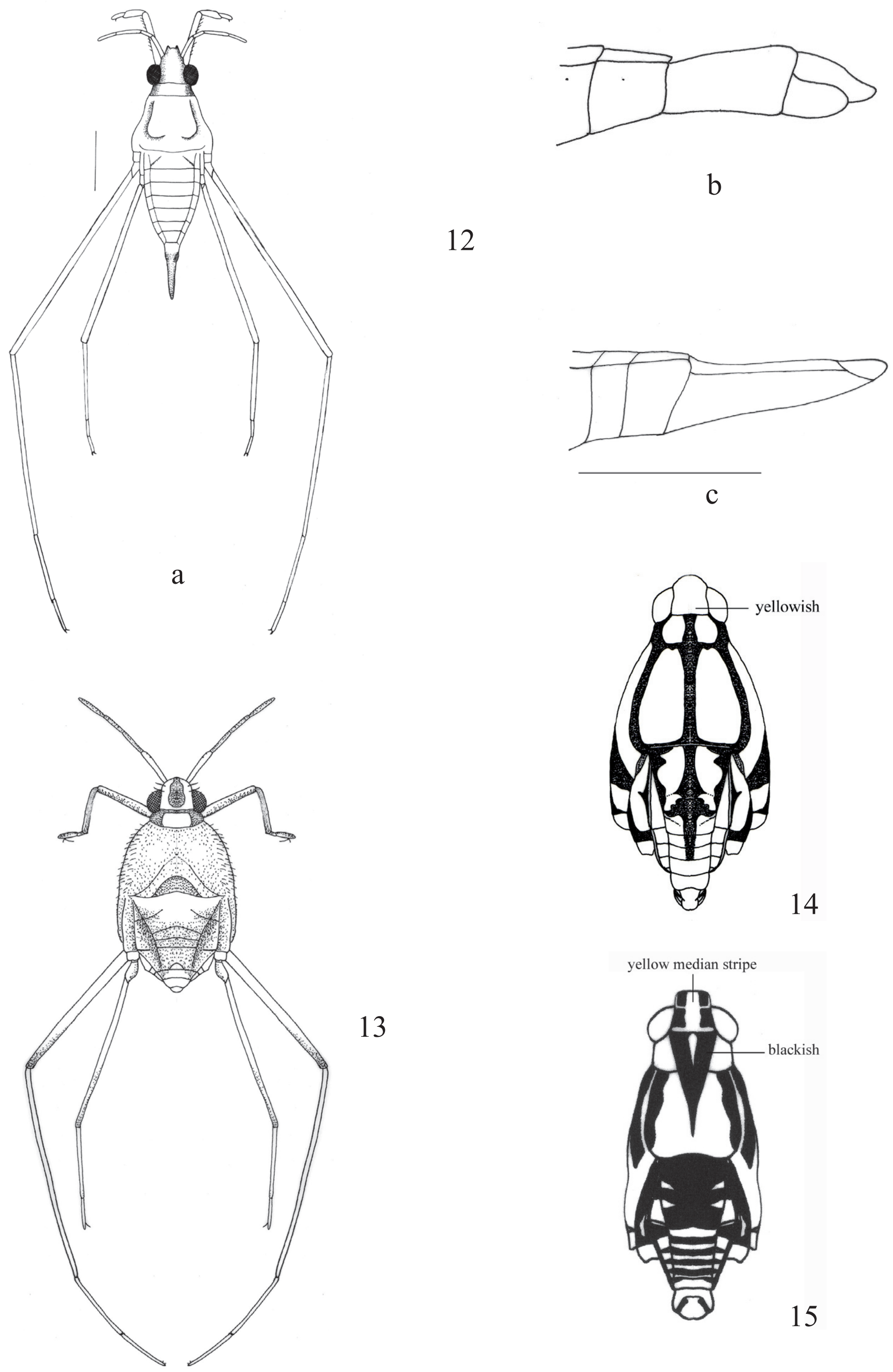

Fig. 12-13 12. Dorsal view of apterous female (a), lateral view of tip of male abdomen (b) and lateral view of tip of female abdomen (c) of *Rhagadotarsus kraepelini* (redrawn from Hecher, 1998, fig. 3); 13. Dorsal view of apterous form of *Naboandelus signatus* (redrawn from Chen & Zettel, 1998, fig. 6,10); 14. Dorsal view of apterous form of *Cryptobates johorensis* (redrawn from Polhemus & Polhemus, 1995, fig. 2); 15. Dorsal view of apterous form of *Gnomobates kuiterti* (redrawn from Polhemus & Polhemus, 1995, fig. 21).
Scale = 1 mm.

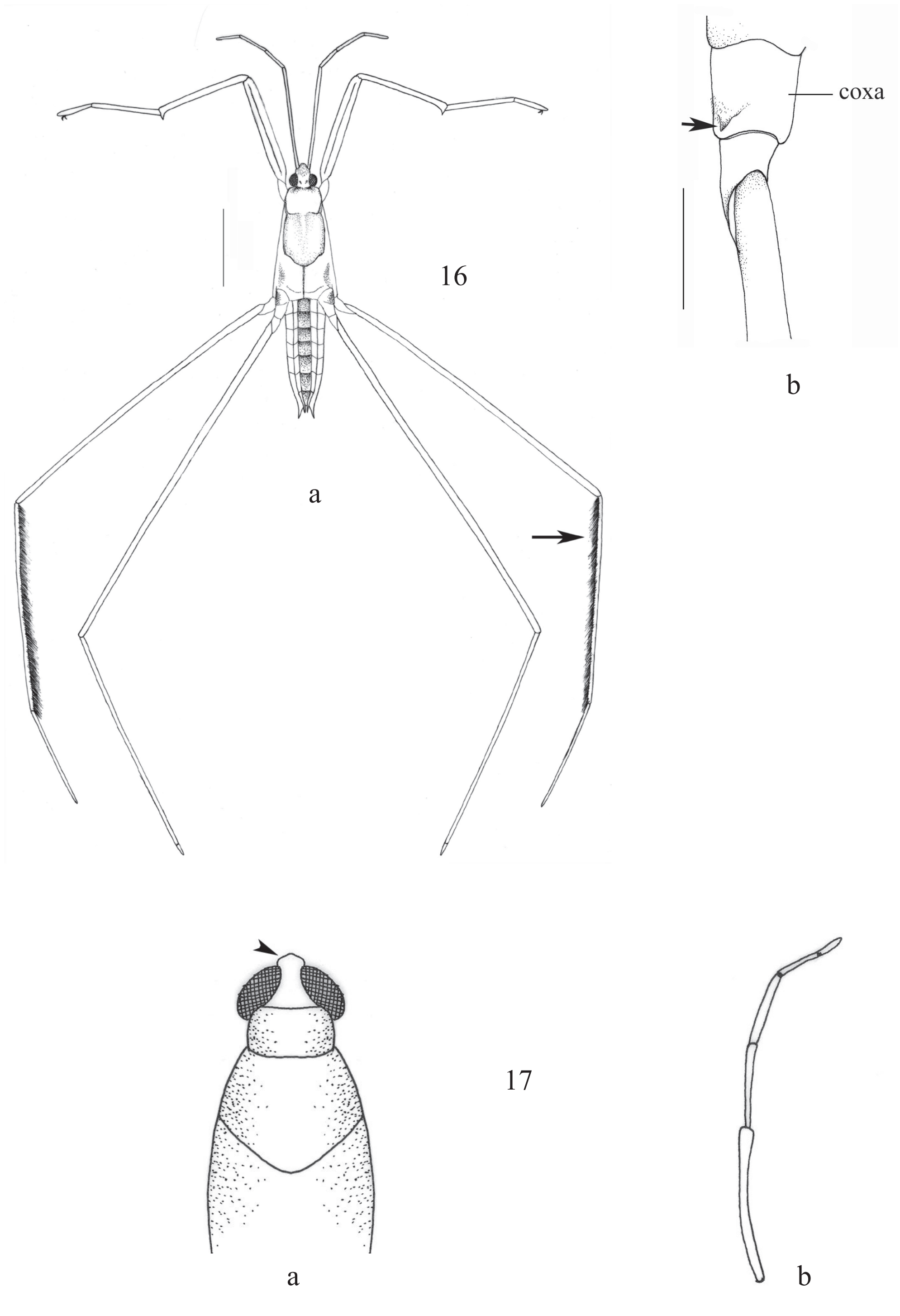

Fig. 16-17 16. Dorsal view of apterous form (a) and ventral view of hind coxa (b) of *Ptilomera tigrina*; 17. Dorsal view (a) and antennae (b) of *Rheumatogonus intermedius* (redrawn from Cheng & Fernando, 1969, fig. 207,196). Scale: (16a) 5 mm; (16b) 1 mm.

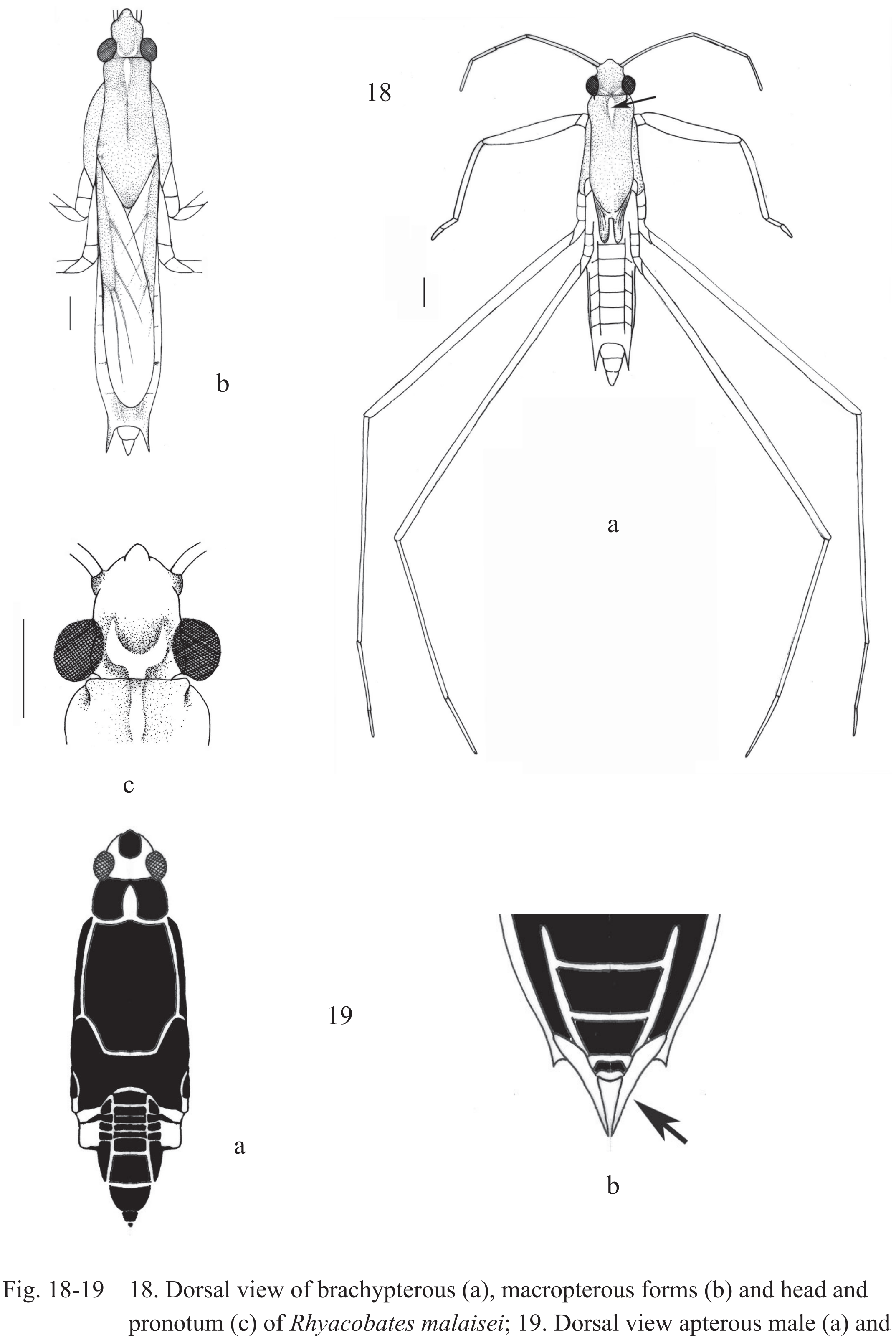

Fig. 18-19 18. Dorsal view of brachypterous (a), macropterous forms (b) and head and pronotum (c) of *Rhyacobates malaisei*; 19. Dorsal view apterous male (a) and dorsal view of apical abdominal segment (b) *Pleciobates* sp. (redrawn from Cheng & Fernando, 1969, fig. 179,193).
Scale = 1 mm.

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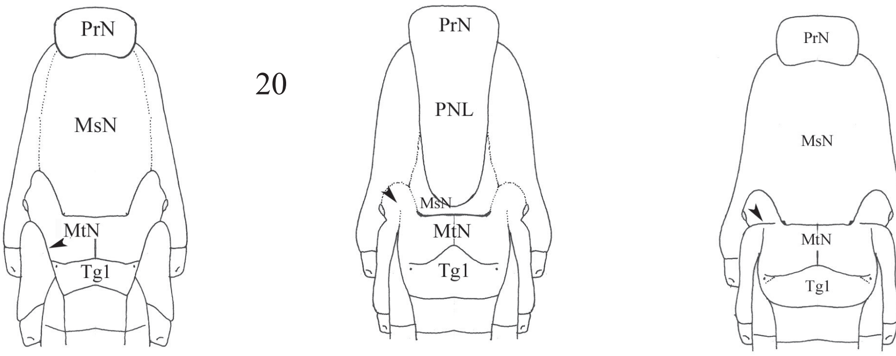

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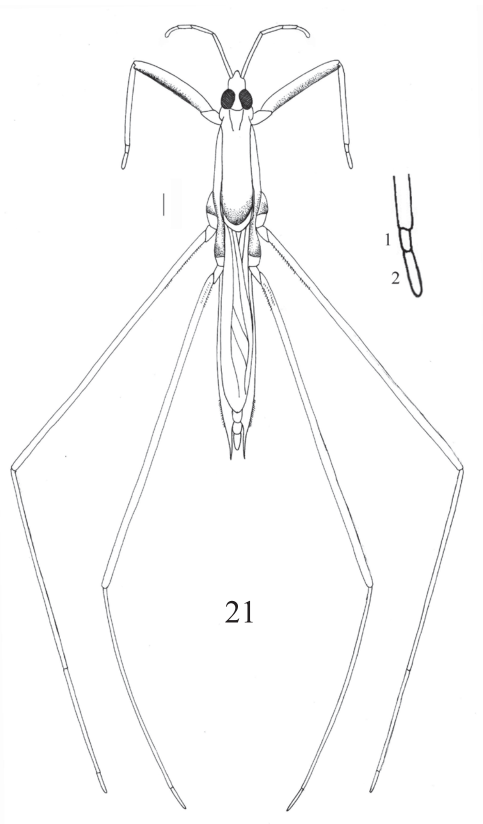

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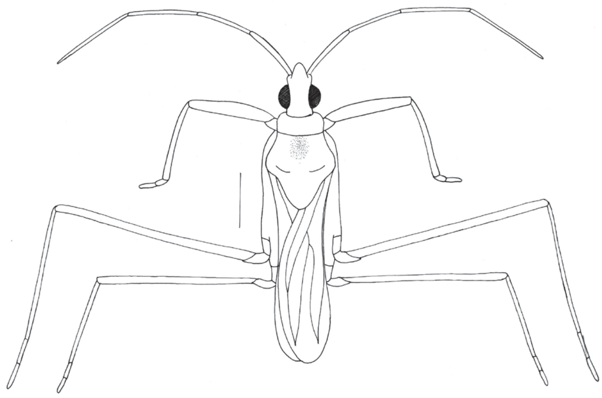

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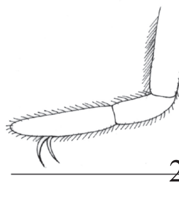

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Fig. 20-23 20. Dorsal view of thorax and base of abdomen of Ptilomerinae (a), Gerrinae (b), Cylindrostethinae (c) (arrows pointing at the metacetabular grooves; MsN=mesonotum, MtN=metanotum, PNL=pronotal lobe, PrN=pronotum, Tg1=tergite I) (redrawn from Chen & Zettel, 1998, fig. 7,8,9). 21. Dorsal view of macropterous form of *Cylindrostethus costalis*; 22. Dorsal view of macropterous form of *Amemboa (Amemboides)* sp; 23. Fore tarsus with claw of *Onychotrechus* sp.
Scale = 1 mm.

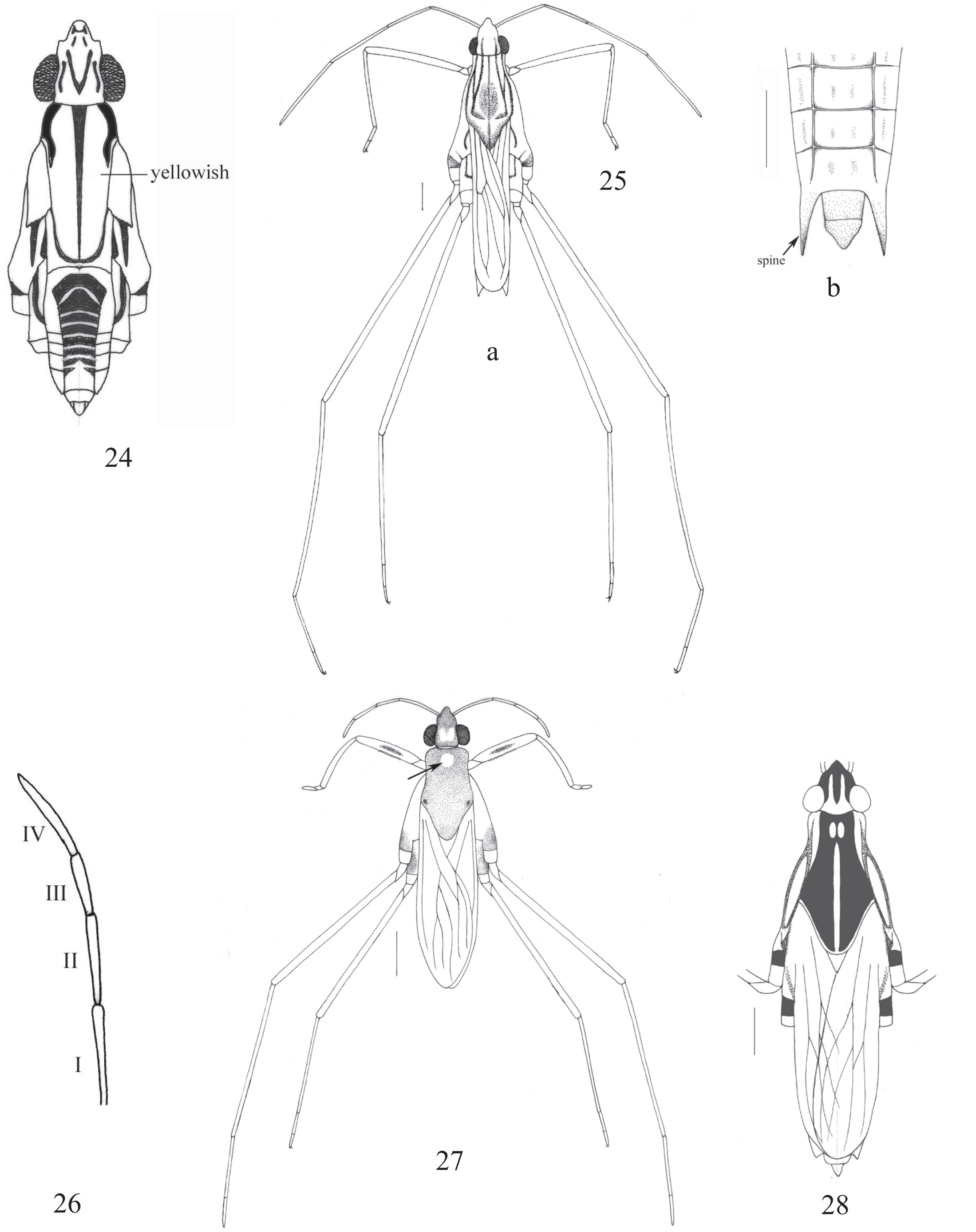


Fig. 24-28 24. Dorsal view of apterous male of *Tenagogonus* sp. (redrawn from Cheng & Fernando, 1969, fig. 34); 25. Dorsal view of macropterous form (a) and posterior end (b) of *Limnometra matsudai;* 26. Antennae (b) of *Gerris* sp. (redrawn from Cheng & Fernando, 1969, fig. 148,153); 27. Dorsal view of macropterous form of *Neogerris parvulus*; 28. Dorsal view of macropterous form of *Limnogonus fossarum* (redrawn from Cheng & Fernando, 1969, fig. 6). Scale = 1 mm.

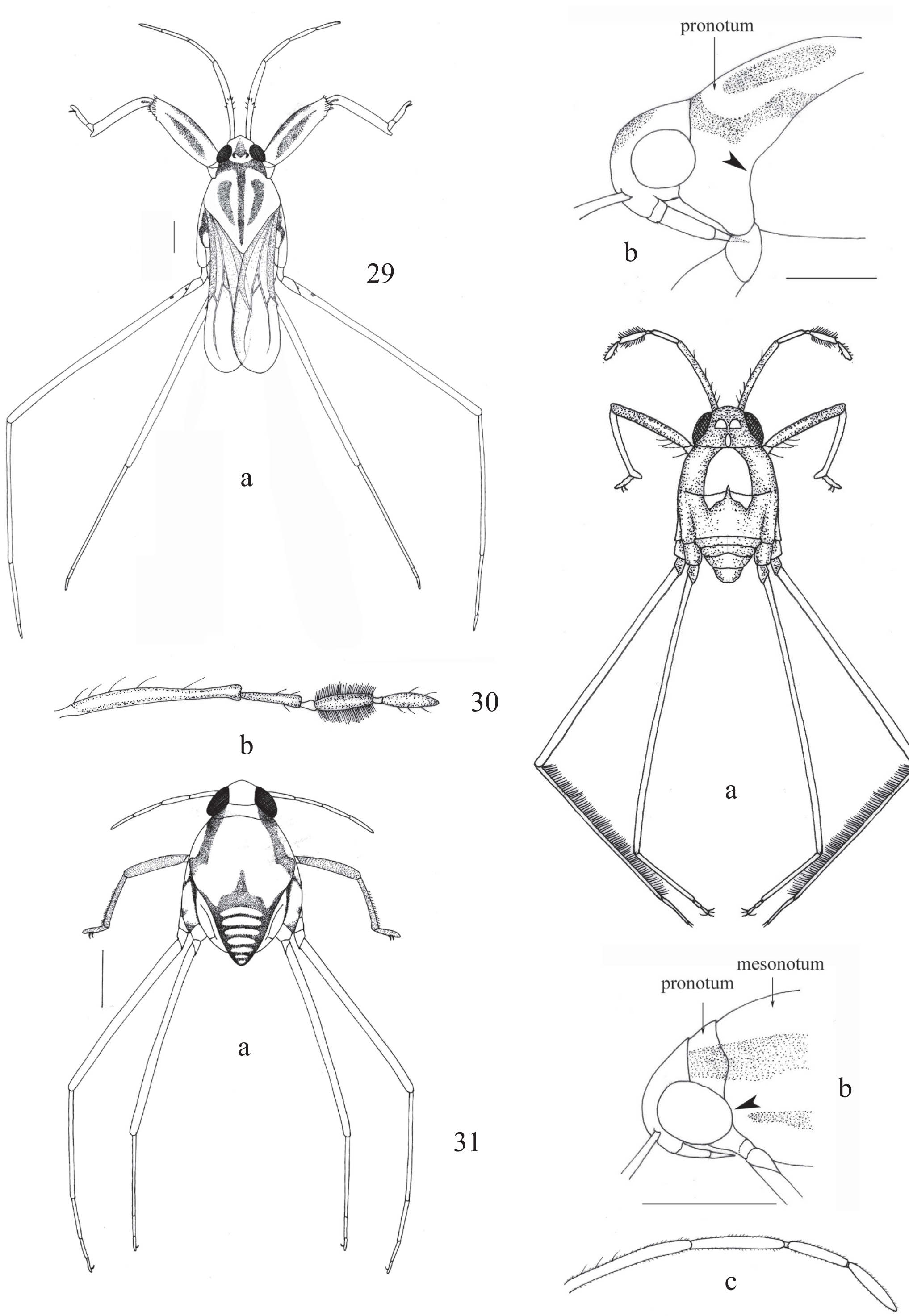


Fig. 29-31 29. Dorsal view of macropterous form (a) and lateral view of head and prothorax (b) of *Metrocoris* sp.; 30. Dorsal view of apterous male (a) and antennae of male (b) of *Esakia* sp. (redrawn from Chen & Zettel, 1998, fig. 25,24) ; 31. Dorsal view of apterous male (a), lateral view of head and prothorax (b), and antennae of male (c) of *Ventidius (Ventidius)* sp. Scale = 1 mm.

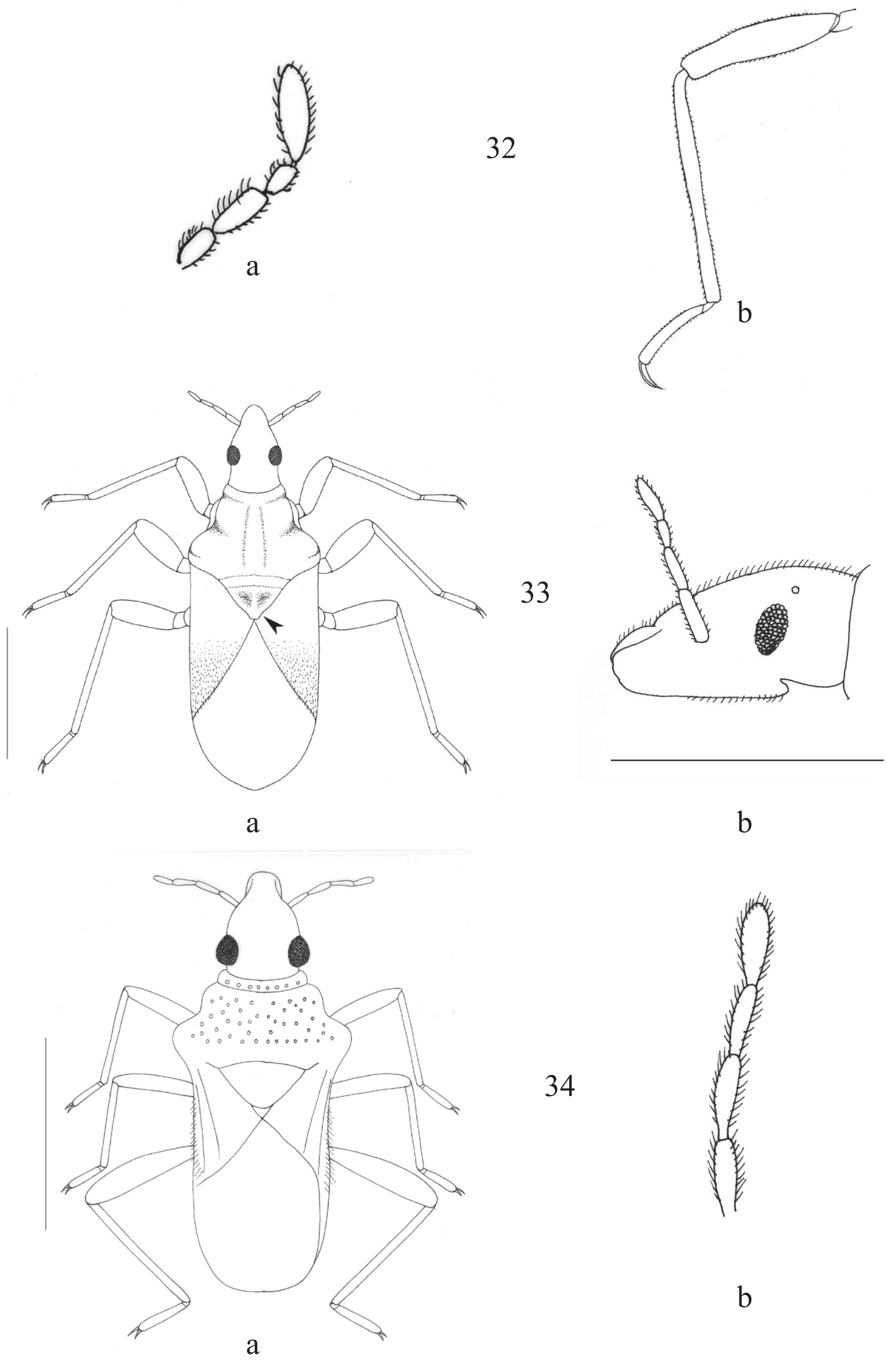
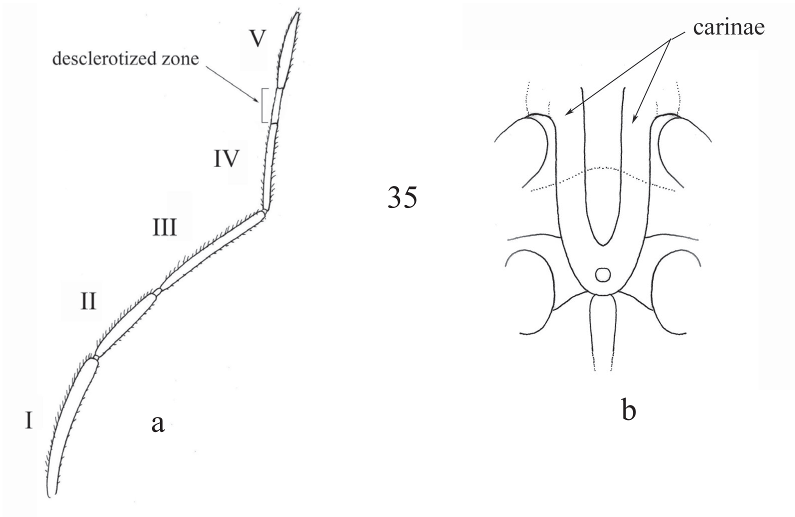


Fig. 32-34 32. Antennae (a) and hind leg (b) of *Nieserius* sp. (redrawn from Zettel, 1999b, fig. 2,6); 33. Dorsal view (a) and lateral view of head (b) of *Hyrcanus* sp. (arrow indicated metanotal elevation); 34. Dorsal view (a) and antennae (b) of *Merragata* sp.
Scale = 1 mm.



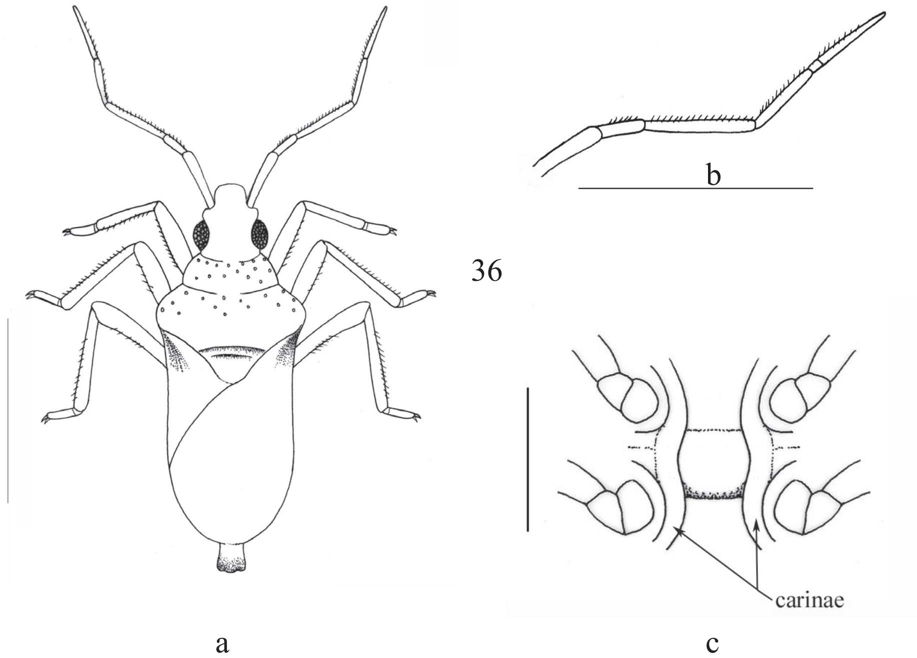


Fig. 35-36 35. Antennae (a) and meso- and metasternum (b) of *Timasius miyamotoi* (redrawn from Zettel, 1999, fig. 5,11); 36. Dorsal view (a), antennae (b) and meso- and metasternum (c) of *Hebrus* sp.
Scale = 1 mm.

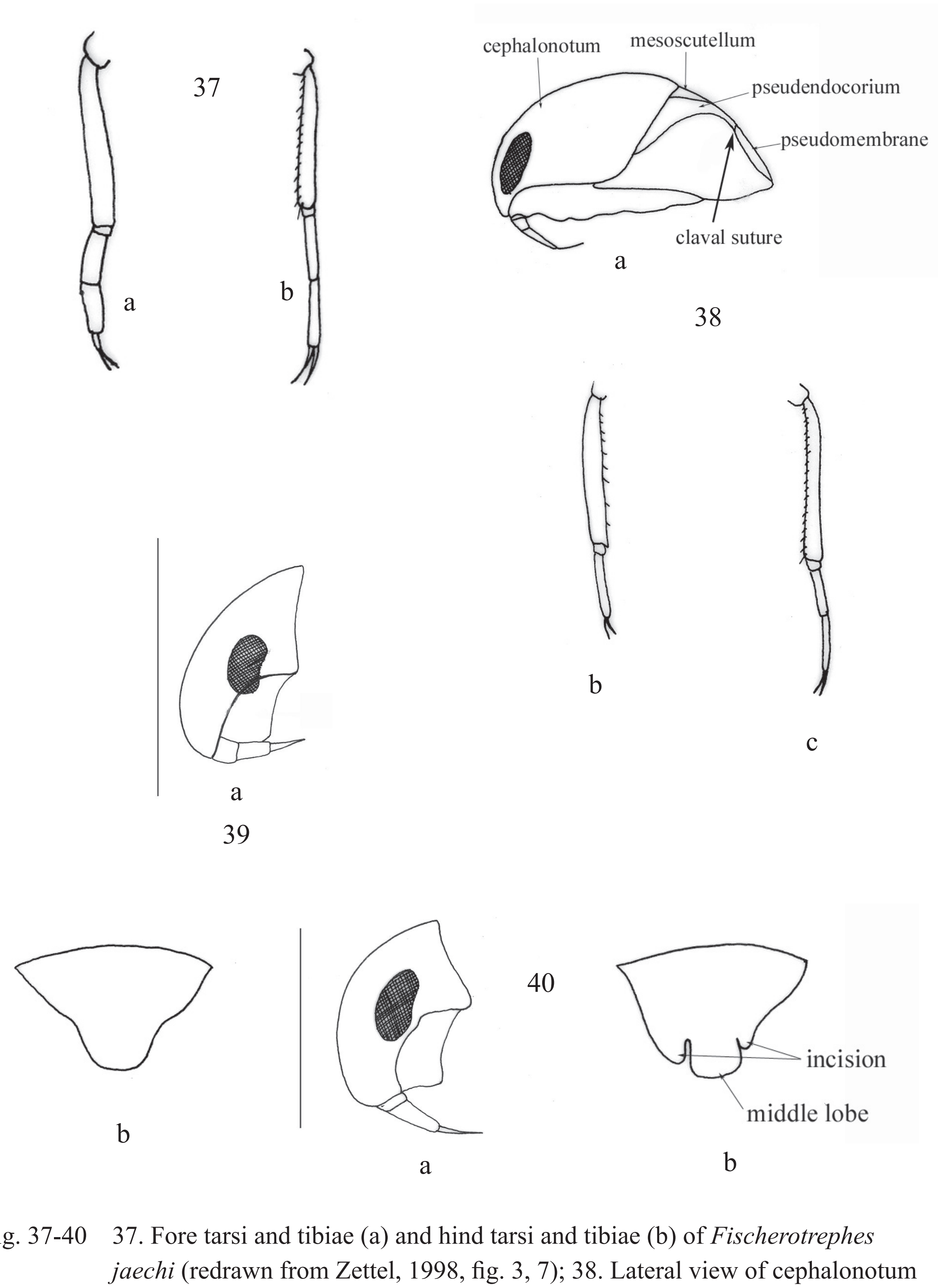
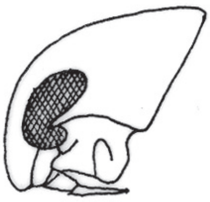


Fig. 37-40 37. Fore tarsi and tibiae (a) and hind tarsi and tibiae (b) of *Fischerotrephes jaechi* (redrawn from Zettel, 1998, fig. 3, 7); 38. Lateral view of cephalonotum (a), fore tarsi and tibiae (b) and hind tarsi and tibiae (c) of *Trephotomas compactus* (redrawn from Zettel, 1998, fig. 1,4,8); 39. Lateral view of cephalonotum (a) and female subgenital plate (b) of *Distotrephes stysi* (redrawn from Zettel, 1998, fig. 12); 40. Lateral view of cephalonotum (a) and female subgenital plate (b) of *Tiphotrephes indicus* (redrawn from Zettel, 1998, fig. 14; Zettel, 1999b, fig, 1).
Scale = 1 mm.



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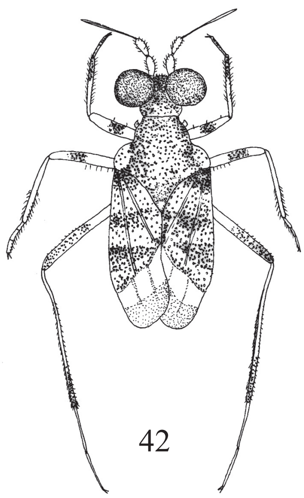

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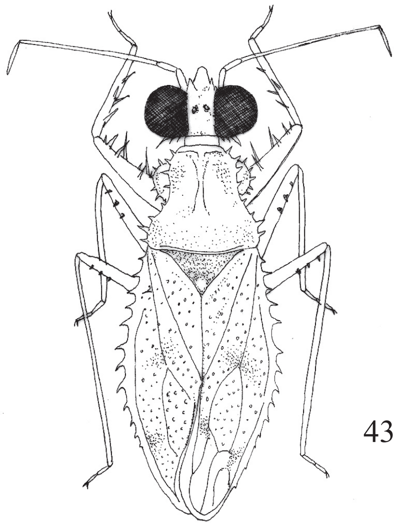

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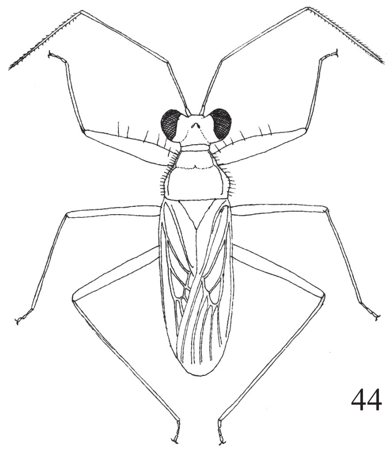

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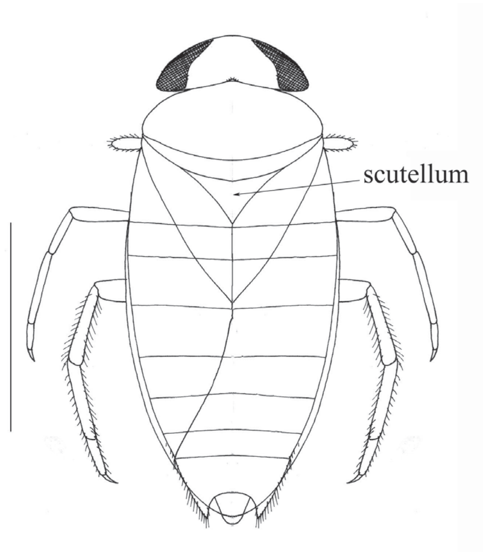
Fig. 41-44 41. Lateral view of cephalonotum (a) and female subgenital plate (b) of *Idiotrephes* sp. (redrawn from Zettel, 1998, fig. 13; Zettel, 1999b, fig, 2); 42. Dorsal view of *Leotichius* sp. (redrawn from Polhemus & Polhemus, 1999, fig. 4); 43. Dorsal view of *Patapius (Pseudopatapius) thaiensis* (redrawn from Polhemus & Polhemus, 1999, fig. 2); 44. Dorsal view of *Valleriola* sp. (redrawn from Polhemus & Polhemus, 1999, fig. 3).



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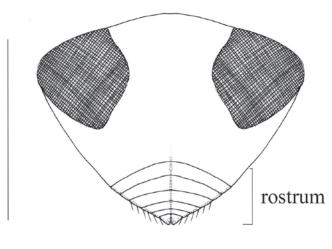

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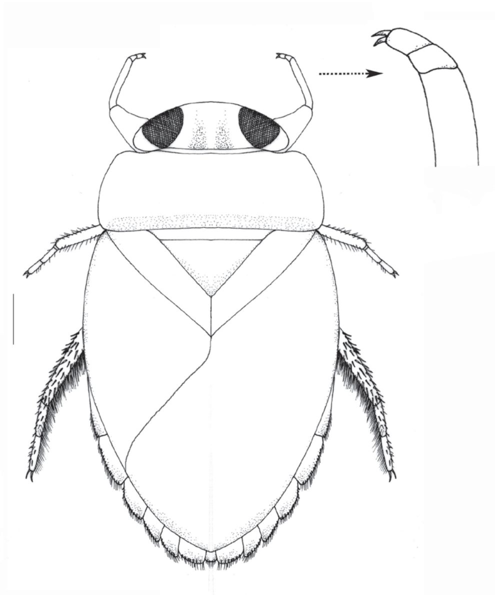

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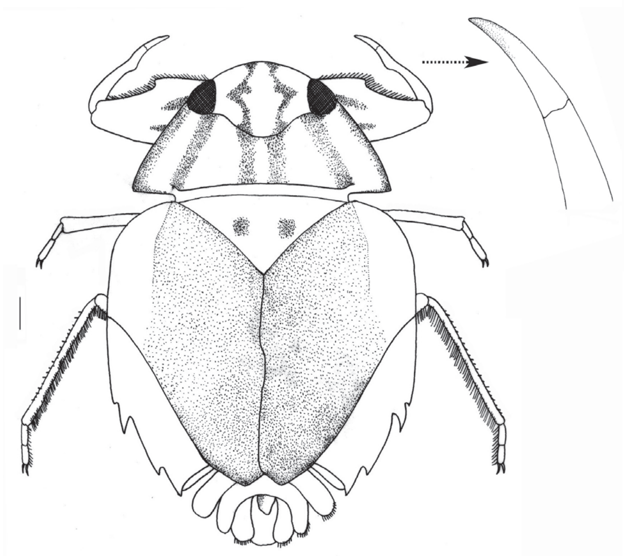

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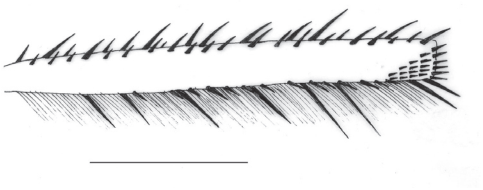

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Fig. 45-47 45. Dorsal view (a) and ventral view of rostrum (b) of *Micronecta* sp.; 46. Dorsal view of *Naucoris* sp.; 47. Dorsal view (a) and distal end of metatibia (b) of *Heleocoris* sp.
Scale = 1 mm.

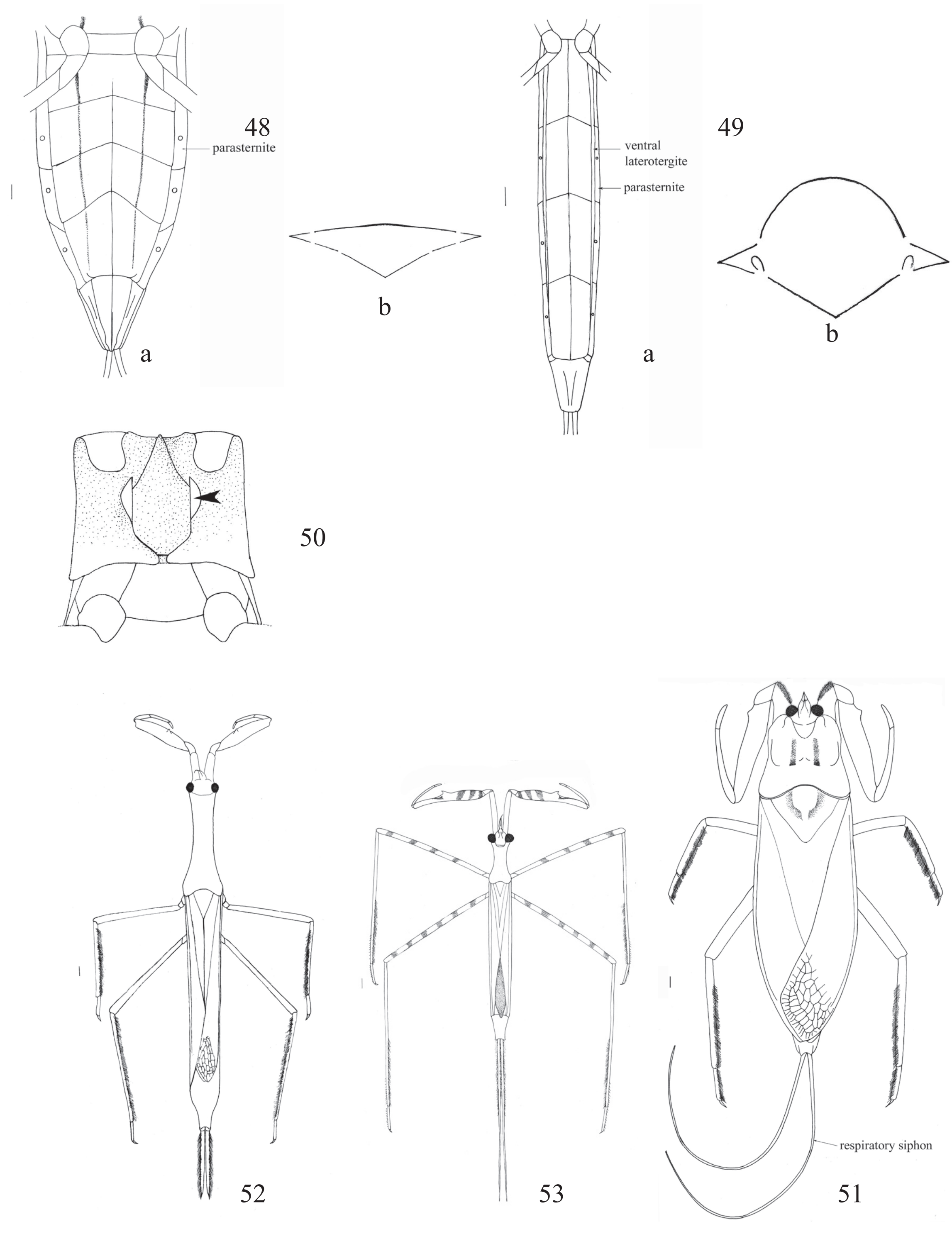


Fig. 48-53 48. Ventral view of abdomen (a) and schematic cross section (b) of Nepinae (redrawn from Nieser & Polhemus, 1998, fig. 2); 49. Ventral view of abdomen (a) and schematic cross section (b) of Ranatrinae (redrawn from Nieser & Polhemus, 1998, fig. 4). 50. Prosternum and mesosternum of *Telmatotrephes* sp. (arrow indicated spircularaperture) (redrawn from Nieser & Polhemus, 1998, fig. 8); 51. Habitus of *Laccotrephes* sp.; 52. Habitus of *Cercotmetus* sp.; 53. Habitus of *Ranatra* sp.
Scale = 1 mm.

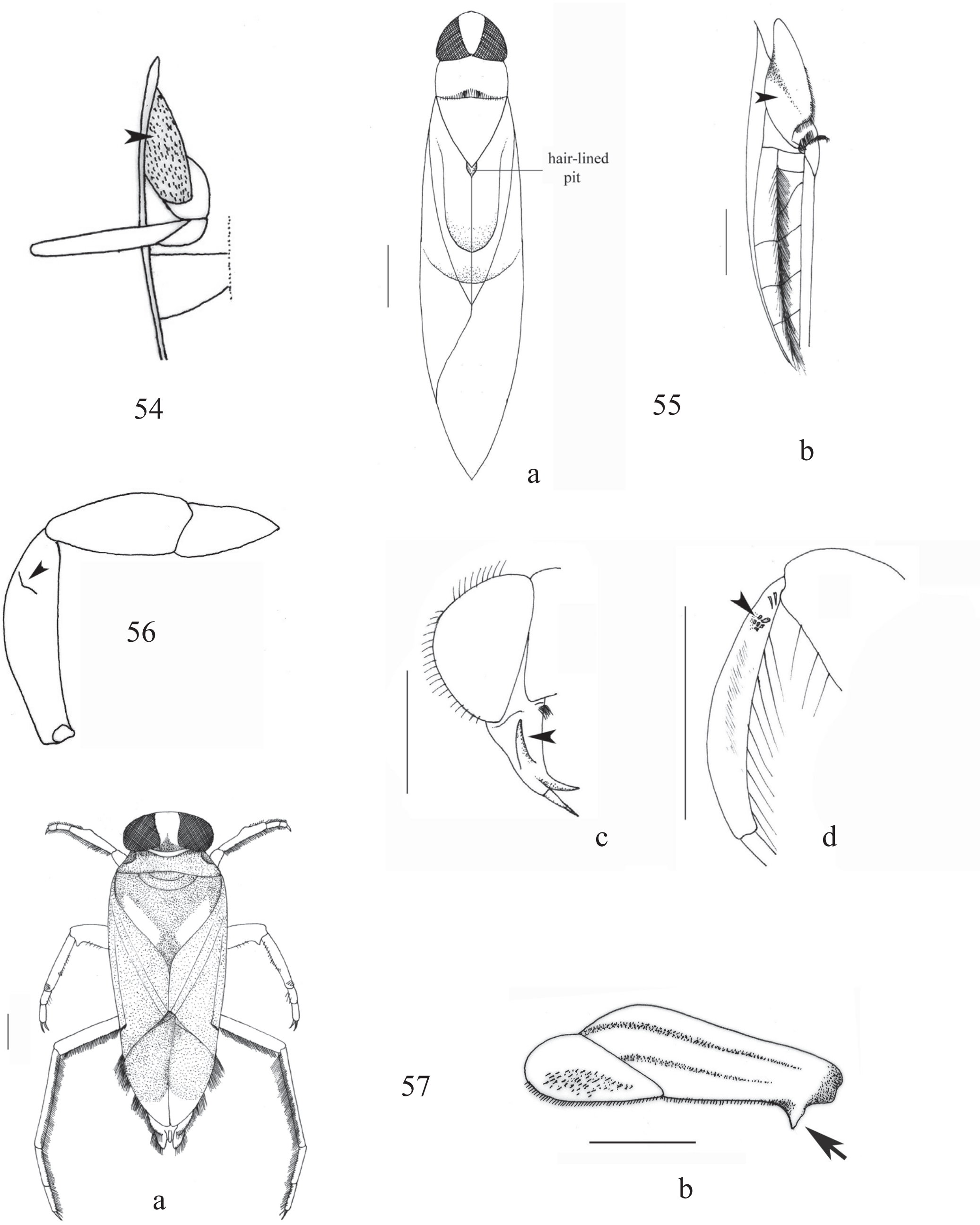


Fig. 54-57 54. Ventral view of right side of metathorax and base of abdomen (arrow indicates coxal plate with setae) of *Paranisops* sp. (Notonectidae) (redrawn from Nieser, 1998, fig. 2); 55. Dorsal view (a), ventral view of right side of metathorax and base of abdomen (b) (arrow indicated coxal plate), lateral view of tibia of rostrum (c) and fore leg (d) (arrow indicates tibial protuberance with closely packed pegs and rostral prong) of *Anisops* sp.; 56. Trochanter, femur and tibia of fore leg of *Walambianisops wandjina* (redrawn from Nieser, 1998, fig. 5) (arrow indicates tibial pegs not on protuberance and not closely packed together); 57. Dorsal view (a) and mid femur (b) of *Enithares* sp. (Notonectidae), arrow indicates ante-apical protuberance.
Scale = 1 mm.

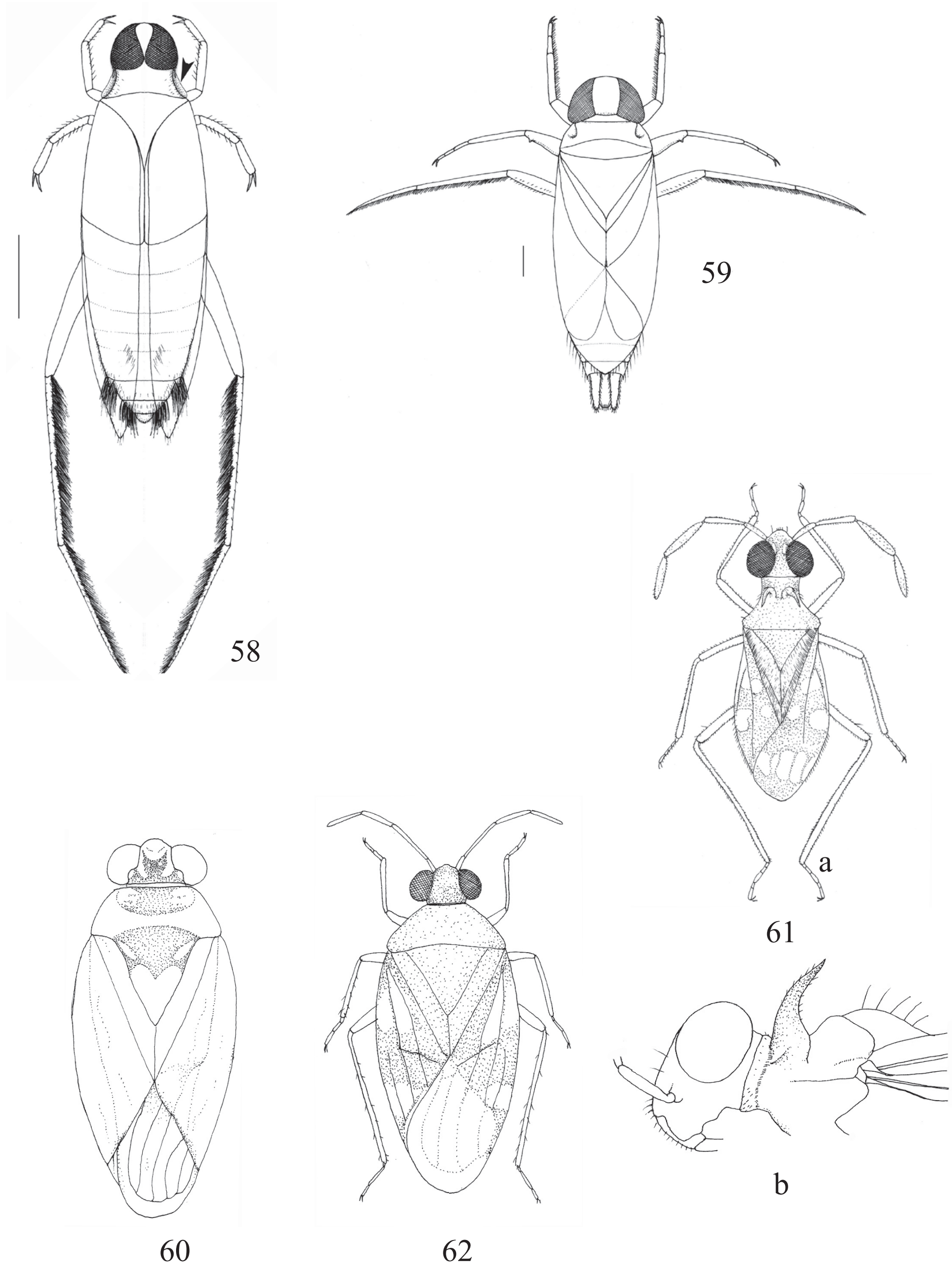


Fig. 58-62 58. Dorsal view of *Nychia sappho* (arrow indicates pronotal fovea and ocular commissure); 59. Dorsal view of *Aphelonecta gavini*; 60. Dorsal view of *Pentacora* sp. (redrawn from Polhemus & Polhemus, 1999, fig. 7b); 61. Dorsal view (a) and lateral view of head and thorax (b) of *Saldoida armata* (redrawn from Polhemus & Polhemus, 1999, fig. 8a-b); 62. Dorsal view of *Saldula* sp. (redrawn from Polhemus & Polhemus, 1999, fig. 4.).
Scale = 1 mm.

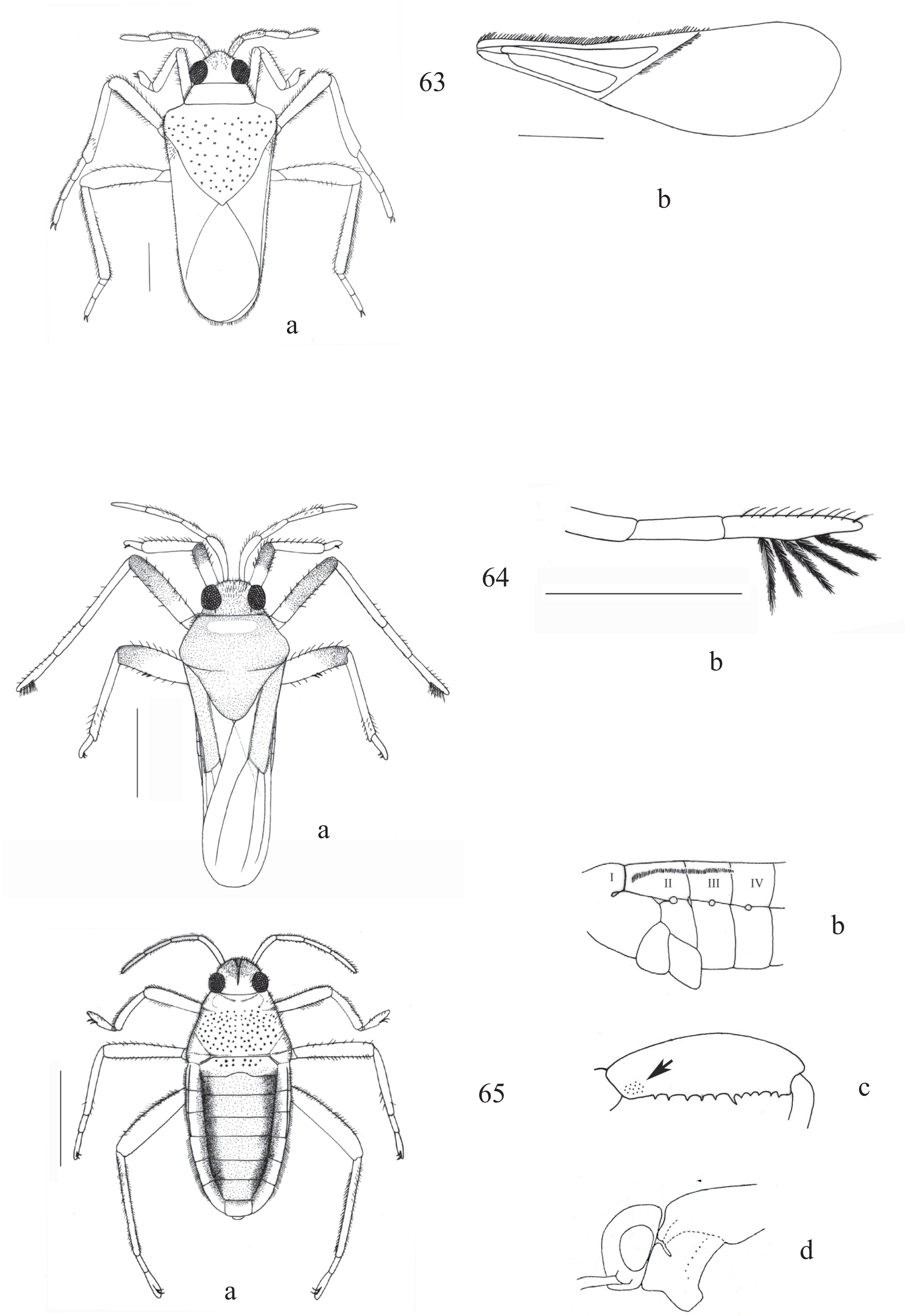
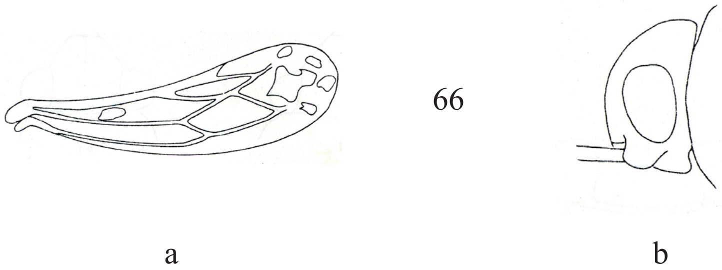
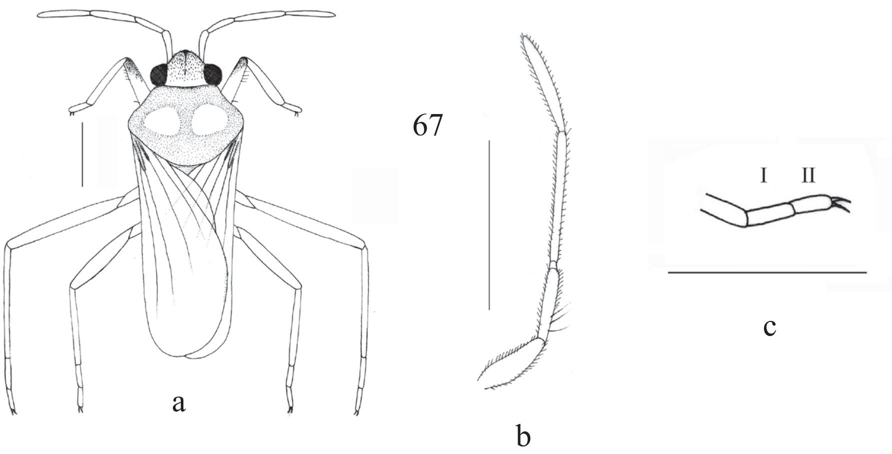
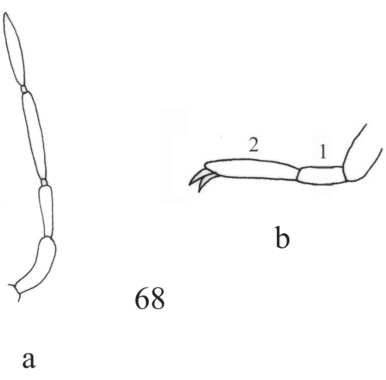


Fig. 63-65 63. Dorsal view (a) and fore wing (b) of *Perittopus* sp.; 64. Dorsal view (a) and swimming fan of mid-leg (b) of *Rhagovelia* sp.; 65. Dorsal view of apterous female (a), lateral view of sternites II-IV (b), lateral view of male hind femur (c) and lateral view of head and pronotum (d) of *Chenevelia stridulans* (redrawn from Hecher, 1998, fig. 5,6,7).
Scale = 1 mm.







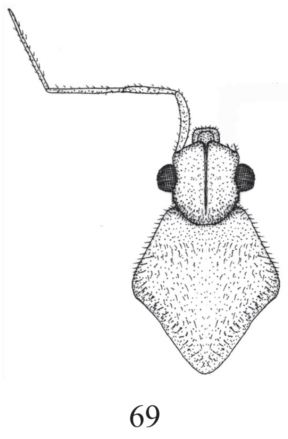
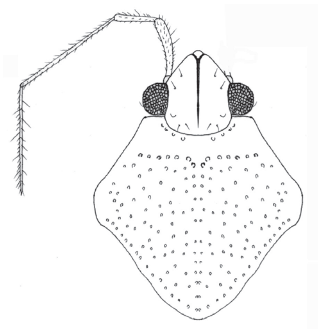


Fig. 66-69 66. Fore wing, (a) and lateral view of head (b) of *Angilia orientalis* (redrawn from Hecher, 1998, fig. 4 ,9); 67. Dorsal view of adult (a), antennae (b) and hind tarsus (c) of *Strongylovelia* sp.; 68. Antennae (a) and hind tarsus (b) of *Entomovelia* sp. (redrawn from Hecher, 1998, fig. 18,23); 69. Dorsal view of head and pronotum of *Lathriovelia capitata* (redrawn from Hecher, 1998, fig. 43).
Scale = 1 mm.



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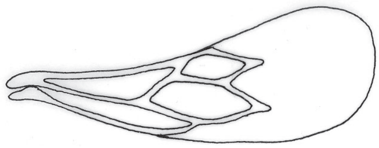

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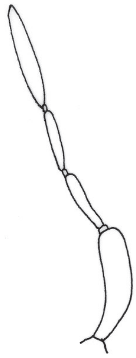

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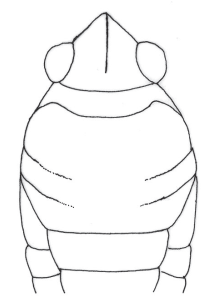

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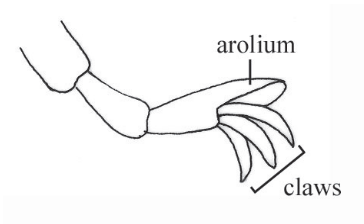

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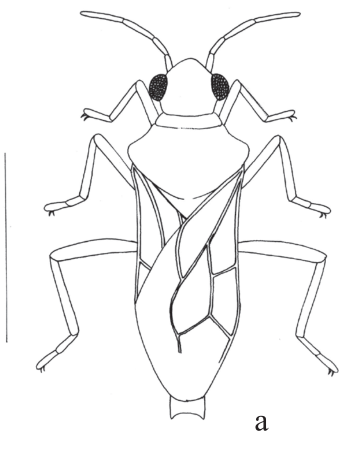

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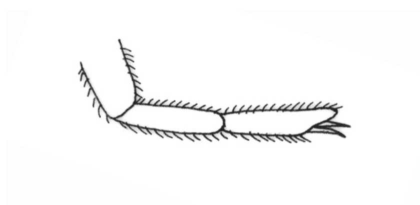

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Fig. 70-73 70. Dorsal view of head and pronotum of macropterous female of *Baptista gestroi*; 71. Fore wing (a) and antennae (b) of *Pseudovelia* sp. (redrawn from Hecher, 1998, fig. 2,20); 72. Head and thoracic nota (a) and middle tarsus (b) of *Xiphovelia* sp. (redrawn from Hecher, 1998, fig. 11, 21); 73. Dorsal view (a) and middle tarsus (b) of *Microvelia* sp.; (redrawn from Hecher, 1998, fig. 1).
Scale = 1 mm.

Chapter 20 Orders Megaloptera and Neuroptera

Order Megaloptera

The alderflies and dobsonflies have aquatic larvae. They include about 200 species worldwide. New and Theischinger (1992) have summarized the published information on Megaloptera, but information on taxa from Indochina is not available. A key to genera of megalopteran larvae from China is available in Yang & Yang (1994) but it is incomplete and does not fit the Indochina species. Here we provide a key to the families and subfamilies of Indochina megalopterans. Two families are commonly found: Sialidae and Corydalidae. They have campodeiform larvae, and feed on various animals in streams and rivers. The well-developed mandibles and lateral abdominal gills make them resemble a small centipede. Sialid larvae have seven pairs of lateral abdominal gills, and the apical abdominal segment lacks prolegs but has a long terminal filament. They burrow into fine sediments. Corydalid larvae have eight pairs of lateral abdominal gills, and the apical abdominal segment has two pairs of clawed prolegs and no long terminal filament. They usually sit beneath cobbles in undisturbed or less disturbed streams.

Order Neuroptera

Most neuropteran larvae are terrestrial insects, but worldwide, three families are known to be aquatic. Only the spongillaflies, family Sisyridae, are common. No specimens of spongillafly larvae were found in this study. However, the larvae are campodeiform and the mouthparts are modified to be a 'sucking tube' for piercing and sucking out cytoplasm from sponge cells.

KEY TO FAMILIES AND SUBFAMILIES OF MEGALOPTERA OF INDOCHINA

1 Abdominal segments I-VIII with 2 segmented lateral filaments; abdominal segment IX with 2 anal prolegs, each with pair of apical claws (Fig. 1)...... CORYDALIDAE …2

1′ Abdominal segments I-VII with 4-5 segmented lateral filaments; abdominal segment IX without prolegs and apical claws (Fig. 2) ....SIALIDAE

2 Larvae with ventral gill tufts (Fig. 1) .... CORYDALINAE

2′ Larvae without ventral gill tufts .... CHAULIODINAE

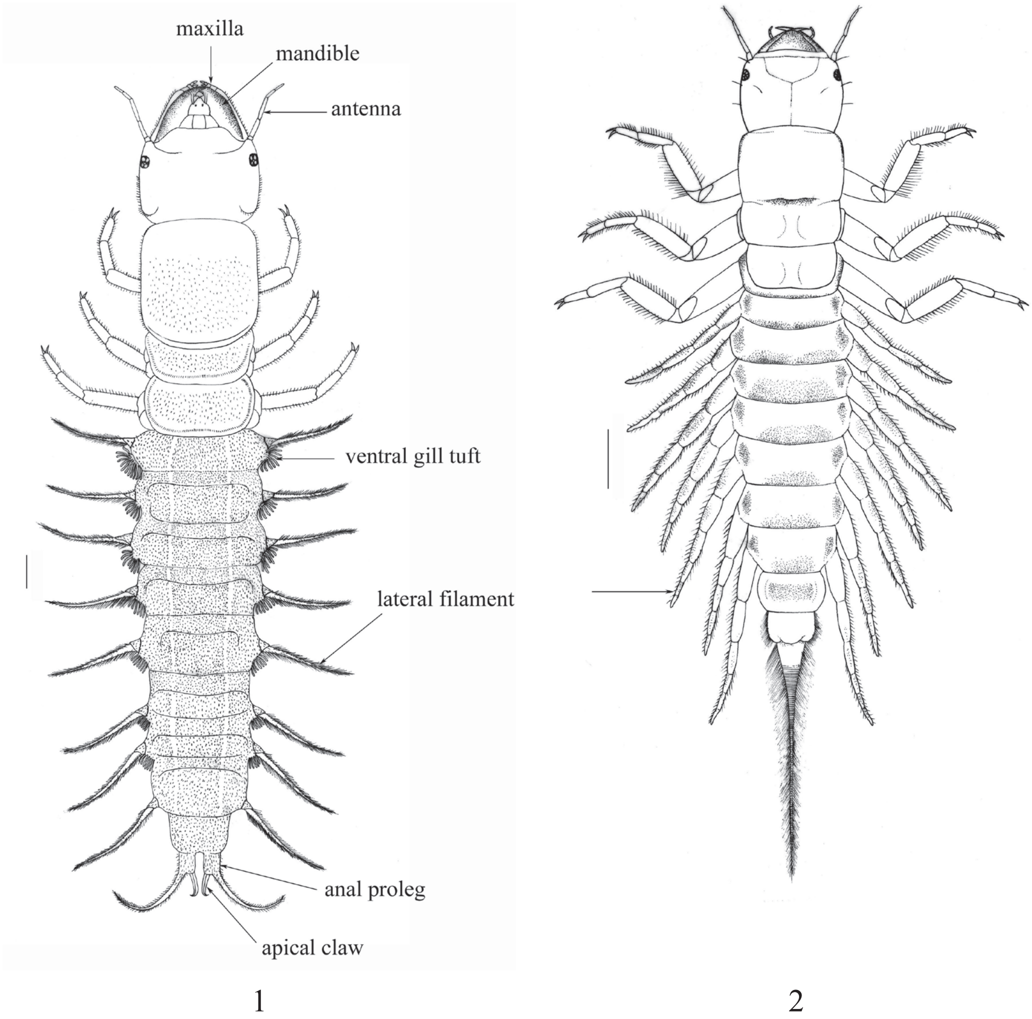


Fig. 1-2 1. Dorsal view of larva of *Protohermes* sp. (Corydalidae); 2. Dorsal view of *Sialis* sp. larva (Sialidae).
Scale = 1 mm.

Chapter 21 Order Trichoptera

The Trichoptera, or caddisflies, is one of the largest orders of aquatic insects, with representatives in all biogeographic regions. There are more than 11,000 species presently known globally (Morse, 2004). They comprise three suborders: Spicipalpia, Annulipalpia and Integripalpia. Twenty-eight families of tropical Asian caddisflies were recorded by Dudgeon (1999). Larvae are campodeiform or eruciform, and are able to emit silk from an opening at the tip of the labium. Silk is used to make larval nets, retreats and portable cases. Larvae are very diverse and occur in most types of freshwater habitats. They have representatives in all functional feeding groups. This is a consequence of their broad ecological diversity. Pupation almost always occurs underwater, and the pupae are enclosed in a cocoon. Pupation takes about two weeks, and the pupa uses large mandibles to cut through the case, freeing the emerging pharate adult. Adults sit on riparian vegetation and feed on nectar. Almost all research done in Asia focuses on descriptions of adults. Ulmer, Martynov, Kimmins and Schmid were the pioneers in the study of adults in China, India, Pakistan and Borneo (see details in Dudgeon, 1999). Other studies were done by: Tanida (1986a, 1986b, 1987: Japan), Chantaramongkol & Malicky (1989, 1995: Thailand), Malicky (1989a, 1989b: Sumatra, 1995: Vietnam), Malicky & Chantaramongkol (1989a, 1989b, 1991, 1992, 1993a, 1993b, 1997: Thailand), and Malicky *et al.* (2001, 2002: Thailand). Since almost all of the works have been done on the adult stage, research on larvae is very limited (due to the inability to identify larvae to genera and species). The following keys to genera are modified from those of Wallace *et al.* (1990), Edington & Hildrew (1995) and Wiggins (1996), and also from studies on the association of larvae and adults of some caddisflies in Thailand (Radomsuk (1999), Chaiyapa (2001), Sangpradub *et al* (1999), Payupwatanawong (2001) and Sirisinthuwanit (2001)). Some characteristics of *Ganonema* larvae (Calamoceratidae) cited here differ from those cited by Wiggins *et al.* (1994). They cite the abdomen as having only gills with single filaments. But gills on reared larvae of *G. extensum* have three filaments on the dorsal side and two on the lateral side (Sirisinthuwanit, 2001). So, in the present key, gills of *Ganonema* are cited as having two and three filaments.

Key to Families of Mature Trichoptera Larvae of Indochina

1 Dorsum of each thoracic segment covered with a large sclerotized plate (Fig. 1)... 2
1′ Meta-or mesothoracic segments membranous (Fig. 4a).. 7

2(1) Ventrolateral gills on abdominal segments (Fig. 24a, 27a, 28a); anal prolegs with a terminal brush of long setae (Fig. 33a); larval net constructed in fast-flowing water .... Hydropsychidae (p. 183)
2′ No ventrolateral gills on abdominal segments; anal prolegs without a terminal brush of long setae 3

3(2′) Abdominal tergum IX without a sclerite 4
3′ Abdominal tergum IX with a sclerite (Fig. 2c)... 5

4(3) Thoracic terga heavily sclerotized; all tarsal claws similar in size (Fig. 1); larva in fixed retreat .... ECNOMIDAE, *Ecnomus*

4′ Thoracic terga weakly sclerotized and with dark bar on metathoracic segment (Fig. 18a-b); metathoracic claws shorter than claws of pro- and mesothoracic legs; larva in fixed or buried tube .... DIPSEUDOPSIDAE, (p. 185) *Pseudoneureclipsis*

5(3′) Abdominal segment I with lateral humps (Fig. 2b) 6

5′ Abdominal segment I without dorso- and lateral humps; no lateral fringes of bristles on abdominal segments (Fig. 20a-23a) .... HYDROPTILIDAE (p. 185)

6(5) Abdominal segment I bears dorsal hump; without sternal plates on thorax and abdominal segment I .... ODONTOCERIDAE**,** in part (p. 188)

6′ Abdominal segment I without dorsal hump; venter of thorax and abdominal segment I with sternal plates (Fig. 2b); cases cylindrical, tapered, curved, made of sand grains, fixed on rock in fast flowing stream with attached stalk made of silk (Fig. 2a) .... LIMNOCENTROPODIDAE, *Limnocentropus*

7(1′) Claw of anal prolegs comb-liked (Fig. 3b); larva with a snail shell shaped case (Fig. 3a) .... HELICOPSYCHIDAE, *Helicopsyche*

7′ Claw of anal prolegs not comb-like, although sometimes claw has accessory hook; larva free living or in fixed retreated or in portable case 8

8(7′) Anal prolegs long, at least 4 times as long as claw (Fig. 1) 9

8′ Anal prolegs short, no more than 3 times as long as claw (Fig. 11b) 17

9(8) Labrum membranous and T-shaped (Fig. 47b, 48a); larvae spin fixed sac-shaped nets .... PHILOPOTAMIDAE (p. 189)

9′ Labrum sclerotized 10

10(9′) Trochantin of prothoracic legs broad and hatchet-shaped **(**Fig. 49b**)**; larva in tubular gallery on rock .... PSYCHOMYIIDAE (p. 189)

10′ Trochantin of prothoracic legs pointed (Fig. 9) 11

11(10′) Tarsi of all legs strongly flattened (Fig. 19c); larva burrows in soft sediment and constructs tube of sediment grains .... DIPSEUDOPSIDAE, in part (p. 185)

11′ Tarsi of all legs normal, not flattened 12

12(11′) Dorsum of abdominal segment IX with sclerotized plate (Fig. 2c) 13

12′ Dorsum of abdominal segment IX without sclerotized plate 15

13(12) Tarsi of the first thoracic legs modified into chelae (Fig. 4b); larva never builds larval retreat .... Hydrobiosidae, *Apsilochorema*
13′ Tarsi of the first thoracic legs norma1 14

14(13′) Larva with prosternal plate (Fig. 5b); turtle-shaped case of gravel (Fig. 5a) ....Glossosomatidae (p. 185)
14′ Larva without prosternal plate; larva free-living (Fig. 52a) .... Rhyacophilidae (p. 189)

15(12′) Mesopleuron (Fig. 7c) extended anteriorly as a lobate process (Fig. 7a), tibia and tarsi fused together on all legs (Fig. 7b); larva in fixed tube of sand ....Xiphocentronidae
15′ Mesopleuron not extended anteriorly; tibia and tarsi not fused together 16

16(15′) ...Head prolonged, more than 2 times as long as wide (Fig. 8a-b); larva constructs fixed retreat between large stones or in a crevice .... Stenopsychidae, *Stenopsyche*
16′ Head not prolonged, basal membranous section of each anal proleg equal in length to distal sclerotized section (Fig. 9); larva constructs fixed silk net on substrate in slow flowing stream .... Polycentropodidae

17(8′) Antenna long and prominent, at least 6 times as long as wide (Fig. 39b), or mesonotum with dark bar (Fig. 42); larvae construct cases with varous materials.... ....Leptoceridae (p. 188)
17′ Antenna short, no more than 3 times as long as wide 18

18(17′) Labrum with transverse row of at least 12 setae across central part (Fig. 16e); cases of two pieces of leaves, dorsal piece larger than ventral one (Fig. 16a), or in hollow twig (Fig. 17a); widespread in patches of leaf litter ....Calamoceratidae (p. 185)
18′ Labrum without transverse row of setae or with few setae 19

19(18′) Meso- and metanotum largely unsclerotized and with similar setal arrangement; case of plant materials ....Phryganeidae
19′ Mesonotum largely covered by sclerotized plates; setal arrangement of mesonotum differs from metanotum 20

20(19′) Claw of hind legs stout, with short bristles (Fig. 43b) or long filament (Fig. 44); case of fine sand grains, shield-shaped (Fig. 43a) .... Molannidae (p. 188)
20′ Claw of hind legs not modified.. 21

21(20′) First abdominal segment lacking dorsal and lateral humps (Fig. 10); case of various materials and arrangement .... Brachycentridae
21′ First abdomen with dorsal and/or lateral humps (Fig. 13a).................................. 22

22(21′) First abdomen with dorsal hump 23
22′ First abdomen without dorsal hump 29

23(22) Antennae situated close to anterior margin of head capsule (Fig. 12c)................ 24
23′ Antennae situated some distance from anterior margin of head capsule or eyes (Fig. 15c) 25

24(23) Anal proleg claw with accessory hooks and a sharply angled crook (Fig. 12d); fore trochantin relatively large, with apex hook-shaped (Fig. 12b); portable case of small rock fragments ....Sericostomatidae
24′ Anal proleg with no more than 3-5 setae posteromesad of lateral sclerite; claw without accessory hooks and with a gently curved crook (Fig. 46c); fore trochantin reduced, blunt (Fig. 46d); larval case of coarse rock fragments (Fig. 46a) ....Odontoceridae (p. 188)

25(23′) Anal proleg with a ventral brush of setae and with a dorsal process bearing setae (Fig. 11b); pronotum usually with transverse carina extended as rounded anterolateral lobe (Fig. 11a); cases of sand grains..................... Beraeidae, *Ernodes*
25′ Anal proleg without a ventral brush of setae or dorsal process; pronutum without transverse carina 26

26(24′) Mesopleuron extended as acute process; each half of mesonotum divided into two or three separate plates (Fig. 13b); portable larval case tubular, made of coarse rock fragments, with two or three large stones on each side (Fig. 13a) ....Goeridae
26′ Mesopleuron not extended anteriorly; mesonotum not divide into several plates . 27

27(26′). Pronotum longer than wide; case usually long, slender and slightly curved, made of fine sand or coarse gravel or entirely of silk, or relatively stout and usually with small stone arranged along each lateral side ....Uenoidae
27′ Pronotum wider than long 28

28(27′) Basal setae of each tarsal claw subequal or as long as claw (Fig. 14); case of mineral materials .... Apataniidae
28′ Basal setae of each tarsal claw shorter than claw; case of mineral or plant materials .... Limnephilidae

29(22′) Larva with prosternal horn (Fig. 15b); antenna situated close to anterior margin of eye (Fig. 15c); cases of various materials and arrangment (Fig. 15a)....................... ....Lepidostomatidae
29′ Larva without prosternal horn; antenna situated close to anterior margin of head; case of debrisarranged irregularly ....Phryganopsychidae, *Phryganopsyche*

Family Calamoceratidae—Key to Genera of Calamoceratidae

1 Anterolateral corners of pronotum projection into prominent lobes (Fig. 16b-c); gills each with 2 or 3 branches; hind tibia usually divided (Fig. 16d); case made of 2 leaf pieces, dorsal piece overlapping ventral one (Fig. 16a) .... *Anisocentropus*

1′ Anterolateral corners of each pronotum without prominent lobe (Fig. 17c); dorsal and ventral gills with 3 branches, lateral gills with 2 branches (Fig. 17b); hind tibia usually not divided; case a hollowed-out twig (Fig. 17a)........................*Ganonema*

Family Dipseudopsidae—Key to Subfamilies and Genera of Dipseudopsidae

1 Meso- and metanotal sclerite present (Fig. 18a-b); larval dwelling a fixed tube covered with sand (Fig. 18c) .... Pseudoneureclipsinae, *Pseudoneureclipsis*

1′ Meso- and metanota membranous ....Dipseudopsinae…2

2(1′) Outer edges of mandibles serrate; ventral gills behind metathoracic legs absent; larval dwelling tube buried in sediments .... *Polycentropus*

2′ Outer edge of mandibles with three strong teeth (Fig. 19b); filamentous gills present behind metathoracic legs and between metasternum and abdominal sternum I (Fig. 19a); larval dwelling tube buried in sediments, or sometimes on the surface of soft sediment (Fig. 19d) ....*Dipseudopsis*

Family Glossosomatidae—Key to Genera of Glossosomatidae

1 Mesonotum bearing 2 sclerites (Fig. 5c); anal opening without dark sclerotized line on each side .... *Agapetus*

1′ Mesonotum membranous (Fig. 6); anal opening with dark, sclerotized line on each side...*Glossosoma*

Larvae of *Nepaloptia, Padunia, Poeciloptila* are unknown.

Family Hydroptilidae—Key to Genera of Hydroptilidae

1 Anterior ventral apotome of head triangular (Fig. 20b); case made of silk alone (Fig. 20a) ....*Orthotrichia*

1′ Anterior ventral apotome of head varied but not triangular; case varied 2

2(1′) Dorsum of abdominal segments I-VII with small tergite 3

2′ Dorsum of abdominal segments without tergite.. 5

3(2) Fifth instar larvae free living or builds a fixed case (Fig. 21) ....*Ugandatrichia*

3′ Fifth instar larvae always with cases 4

4(3′) Dorsum of abdominal tergite with ring on the middle .... *Stactobia*
4′ Abdominal terga without ring... *Plethus*

5(2′) All three pairs of legs approximately the same length; larva with 3 apical abdominal gills, one from dorsomedian position on segment IX, other two at lateral sclerite of anal prolegs (Fig. 22b); compressed case made of silk covered with fine sand grain or filamentous algae (Fig. 22a) ....*Hydroptila*
5′ Mid- and hind legs more than 2 times as long as forelegs; larvae without apical anal gills; cases varied.. 6

6(5′) Meso- and metathoracic legs 2.5 times as long as prothoracic legs; larvae in flatted flask-shaped case made of silk (Fig. 23).. *Oxyethira*
6′ Meso- and metathoracic legs 4 times as long as prothoracic legs .... *Tricholelochiton*

Larvae of *Microptila, Chrysotrichia, Sacelotrichia* and *Ptilocolepus* are unknown.

Family Hydropsychidae—Key to Subfamilies and Genera of Hydropsychidae

1 Gena of head capsule completely separated by ventral apotome (Fig. 24b) .... Arctopsychinae…2
1′ Gena of head capsule partially separated by anterior and posterior apotome (Fig. 26a,27c) 3

2(1) Dorsum of most abdominal segments with tuft of several long setae and/or scale setae on sa2 and sa3 positions (Fig. 25); ventral apotome usually nearly rectangular .... *Parapsyche*
2′ Dorsum of most abdominal segments with single long seta on sa2 and sa3 positions (Fig. 24c), frequently with one or two short setae but not a tuft; ventral apotome tapers posteriorly ....*Arctopsyche*

3(1′) Posterior ventral apotome at least one-half as long as median ecdysial line (Fig. 26a); frontocypleus constricted at eye level (Fig. 26b).................................... .... Diplectroninae, *Diplectrona*
3′ Posterior ventral apotome less than one-half as long as median ecdysial line (Fig. 27d); frontocypleus not constricted at eye level 4

4(3′) Abdominal gills with central stalk with numerous filaments arising fairly uniformly along entire length (Fig. 27d); fore trochantin never forked (Fig. 27a,31a,32a)........ ....Macronematinae…5
4′ Abdominal gills with central stalk, mostly gill filaments arising from basal part of central stalk (Fig. 33c); fore trochantin usually forked (Fig. 33a,36a,37a)................ ....Hydropsychinae…10

5(4) Dorsum of head flattened (Fig. 27,28), with sharp carina; fore tibia and tarsus with dense setal fringe (Fig. 27a,28a)... 6
5′ Dorsum of head not flattened and without sharp carina; fore tibia and tarsus without setal fringe (Fig. 29a,31a,32a) 7

6(5) Head broad and short, dorsal ridge sharply marked with crown of setae (Fig. 27b); trapezoidal submentum (Fig. 27c)... *Macrostemum*
6′ Head less broad, dorsal ridge without crown of setae (Fig. 28b); triangular submentum (Fig. 28c)...*Amphipsyche*

7(5′) Head and thorax elongated and narrower than abdomen, head width about one-half as long as its length (Fig. 31b)... 8
7′ Head and thorax not narrower than abdomen, head about as long as wide; (Fig. 29b); abdominal gills with two filaments, gills arranged in single row on each side of abdomen (Fig. 29a)... 9

8(7) Mesosternum with gills; fore trochantin acute (Fig. 31c) .... *Polymorphanisus*
8′ Mesosternum without gills; fore trochantin blunt (Fig. 32b) ....*Oestropsyche*

9(7′) Abdominal gills with two filaments (Fig. 29a)..............................*Pseudoleptonema*
9′ Abdominal gills with more than two filaments (Fig. 30) .... *Trichomacronema*

10(4′) Anterior ventral apotome with remarkable anteromedial projection (Fig. 33b); lateral border of mandible flanged (Fig. 33d)...*Potamyia*
10′ Anterior ventral apotome without remarkable anteromedial projection; lateral border or mandible not flanged... 11

11(10′) Dorsal abdominal segments with scale setae (Fig. 36b,37b).............................. 13
11′ Dorsal abdominal segments without scale setae.. 12

12(11′) Dorsal abdominal segments with only plain setae (Fig. 34b); prosternum with small scerite or absent (Fig. 34a)..*Cheumatopsyche*
12′ Dorsal abdominal segments with plain setae and club setae (Fig. 35b); prosternum with large scerite (Fig. 35a).. *Ceratopsyche*

13(11) Only conical scale setae on abdominal segments (Fig. 36b)...........*Hydatomanicus*
13′ Dorsal abdominal segments with plain setae and scale setae 14

14(13′)....Dorsal abdominal segments with plain setae and long wedge-shaped scale setae (Fig. 38) .... *Hydropsyche*
14′ Dorsal abdominal segments with plain setae and numerous round scale setae (Fig. 37b) .... *Hydromanicus*

Larvae of *Maesaipsyche* not found.

FAMILY LEPTOCERIDAE—KEY TO SUBFAMILIES AND GENERA OF LEPTOCERIDAE

1 Head with secondary cephalic ecdysial lines (Fig. 39b); metanotum thout sclerite or with only one pair of small sclerites at sa3 .... LEPTOCERINAE…2

1′ Head without secondary cephalic ecdysial lines; metanotum with at least two pairs of sclerites; case a hollowed twig, randomly arranged detritus, or empty case of other caddis larva .... TRIPLECTININAE, *Triplectides*

2(1) Mesothoracic legs each with tarsal claw hooked (Fig. 39c); case of silk, strongly tapered and slightly curve (Fig. 39a) .... *Leptocerus*

2′ Mesothoracic legs each with normal tarsal claw 3

3(2′) Anal prolegs each with sclerite (Fig. 40b); or larva with three subequal thoracic segments and undivided tibia on metathoracic legs; head and pronotum with dark spots and small marks; conical case of sand grains (Fig. 40a) .... *Setodes*

3′ Anal prolegs each without sclerites 4

4(3′) Maxillary palp extending far beyond anterior edge of labrum (Fig. 41b); case of mineral and/or plant material (Fig. 41a) .... *Oecetis*

4′ Maxillary palp not extending far beyond anterior edge of labrum.......................... 5

5(4′) Mesonotum with pair of dark, curved or straight bars on weakly sclerotized plates (Fig. 42); case of sand grains with anterior opening wider, tapered posteriorly ....*Ceraclea*

5′ Metanotum without dark bars on sclerites....................................... unknown genus

Larvae of *Adicella, Mystacides, Triaenodes* and *Trichosetodes* are unknown.

FAMILY MOLANNIDAE—KEY TO GENERA OF MOLANNIDAE

1 Tarsal claw of each hind leg much shorter than tarsi, modified into curved broad setose lobe (Fig.43b)..*Molanna*

1′ Tarsal claw of each hind leg as long as tarsus, modified into slender filament (Fig. 44) .... *Molannodes*

FAMILY ODONTOCERIDAE—KEY TO GENERA OF ODONTOCERIDAE

1 Anterolateral corner of pronotum sharp-pointed; each mesonotal plate not divided into small sclerites (Fig. 45) ....*Psilotreta*

1′ Anterolateral corner of pronotum not produced into sharp point (Fig. 46b); each mesonotal plate subdivided into three sclerites (Fig. 46b) .... *Marilia*

Larvae of *Inthanopsyche, Lannapsyche* are unknown.

Family Philopomatidae—Key to Genera of Philopomatidae

1 Anterior margin of frontoclypeus with asymmetrical prominent notch (Fig. 47b); fore coxa with long process arising near distal end (Fig. 47c) .... *Chimarra*

1′ Anterior margin of frontoclypeus convex (Fig. 48a); fore coxa lacking long process (Fig. 48b) ....*Wormaldia*

Larvae of *Doloclanes, Dolophilodes,* and *Gunungiella* not known.

Family Psychomyiidae—Key to Genera of Psychomyiidae

1 Anal claw with conspicuous ventral teeth (Fig. 51b) 3

1′ Anal claw without ventral teeth.. 2

2(1′) Mandible with dorsolateral protubercle, lateral setae near middle of each mandible (Fig. 49d); sclerites of submentum large, half as long as wide (Fig. 49c)......*Tinodes*

2′ Mandible without protubercle, lateral setae arising about one-third of distance from base of each mandible (Fig. 50); sclerites of submentum one-third as long as wide . ...*Lype*

3(1) Submentum longer than wide (Fig. 51a) ....*Psychomyia*

3′ Submentum wider than long...*Paduniella*

Family Rhyacophilidae—Key to Genera of Rhyacophilidae

1 Second segment of maxillary palps longer than the other segments (Fig. 52b); tuft of gills absent or present..*Rhyacophila*

1′ Second segment of maxillary palps not longer than the other segments; tuft of lateral gills on thoracic and abdominal segments (Fig. 53)................ *Himalopsyche*

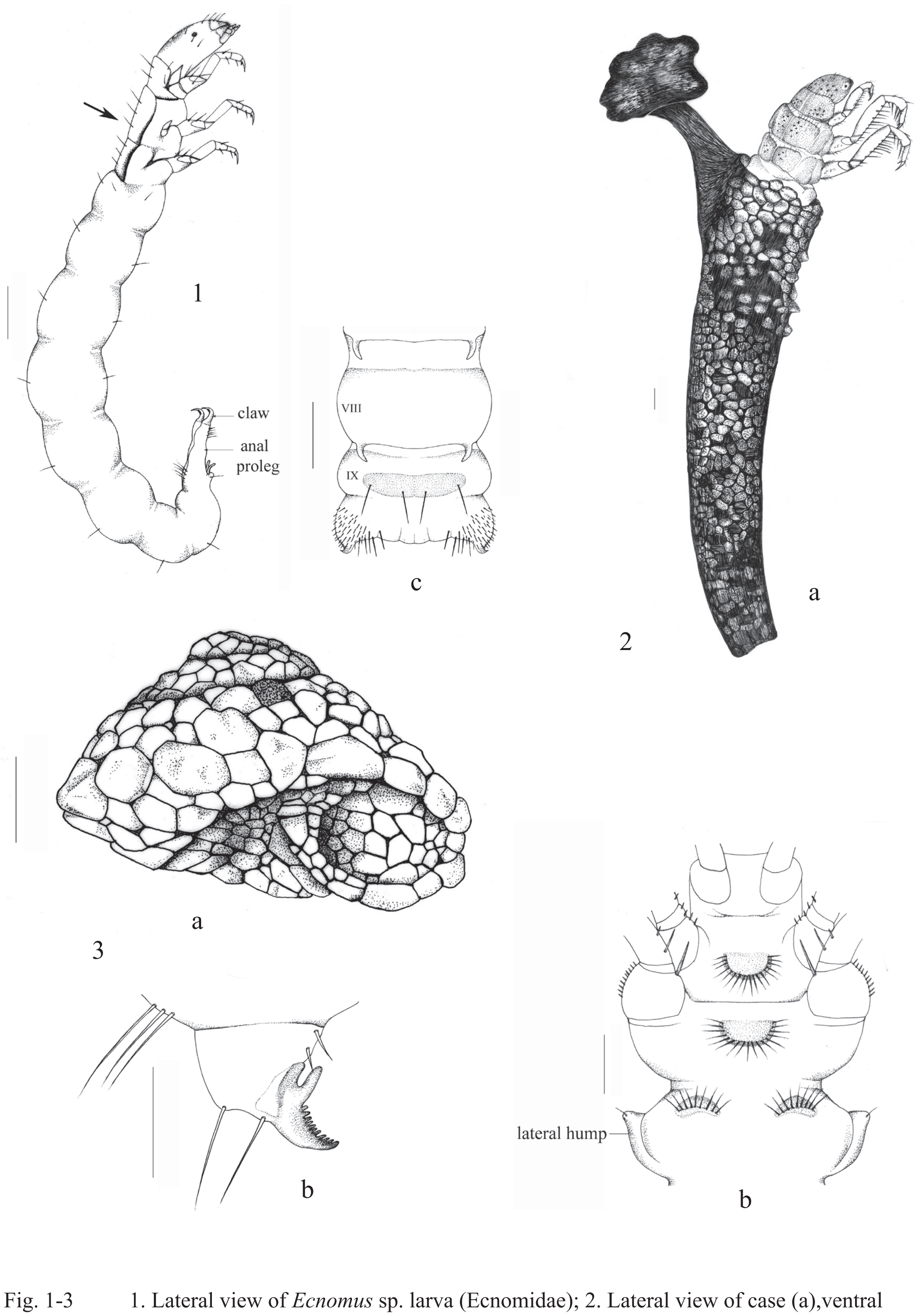


Fig. 1-3 1. Lateral view of *Ecnomus* sp. larva (Ecnomidae); 2. Lateral view of case (a),ventral view of thorax (b) and ventral view of abdominal segment IX (c) of *Limnocentropus* sp. larva (Limnocentropodidae); 3. Portable case (a) and anal hook (b) of *Helicopsyche* sp. larva (Helicopsychidae).
Scale: (1,2a-c,3a) 1 mm; (3b) 0.5 mm

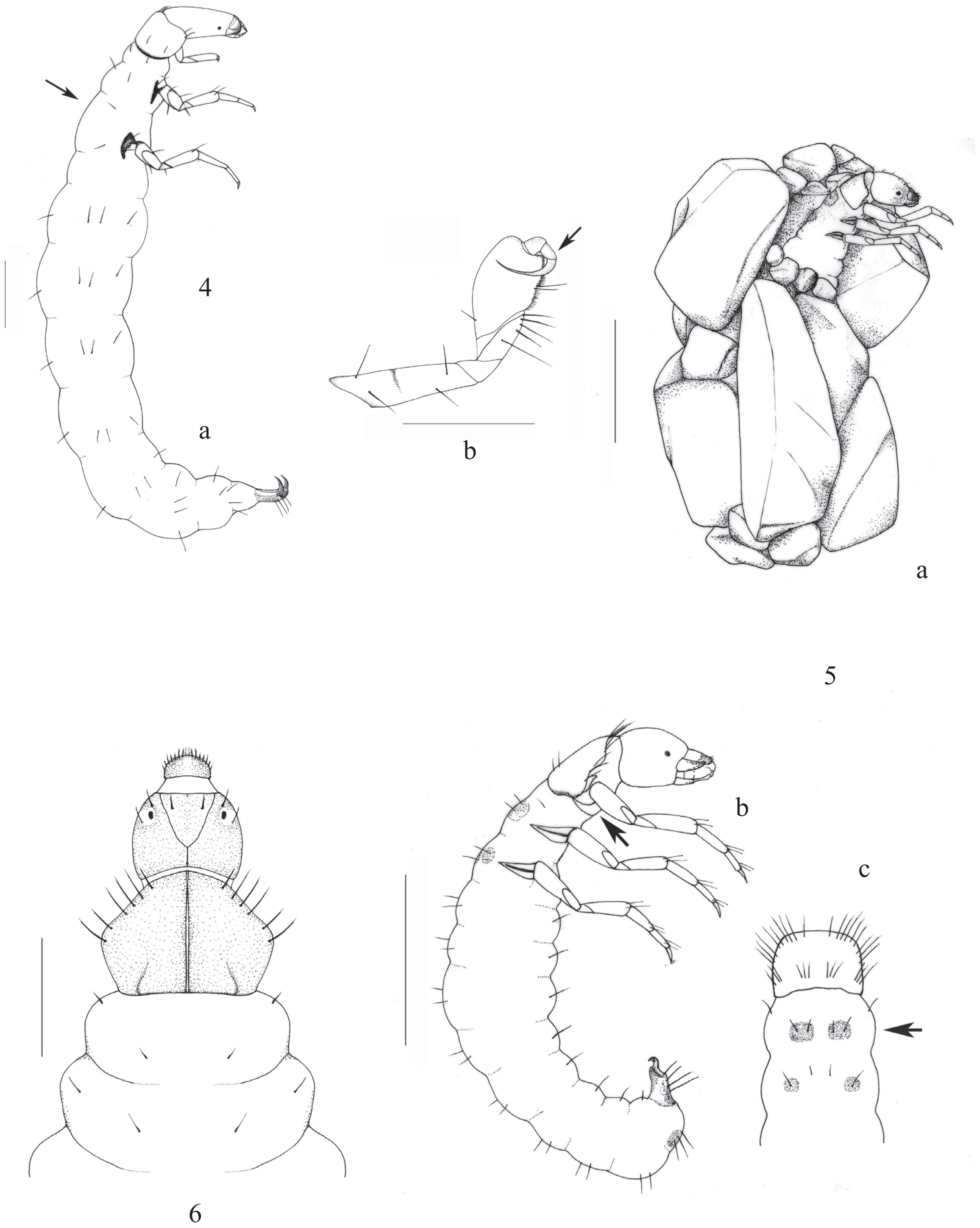


Fig. 4-6 4. Lateral view (a) and foreleg (b) of *Apsilochorema* sp. larva (Hydrobiosidae); 5. Larva in portable case (a) , lateral view (b) and dorsal view of thorax (c) of *Agapetus* sp. larva (Glossosomatidae); 6. Dorsal view of head and thorax of *Glossosoma* sp. larva (Glossosomatidae).
Scale: (4a,5a-c,6) 1 mm; (4b,6b) 0.1 mm.

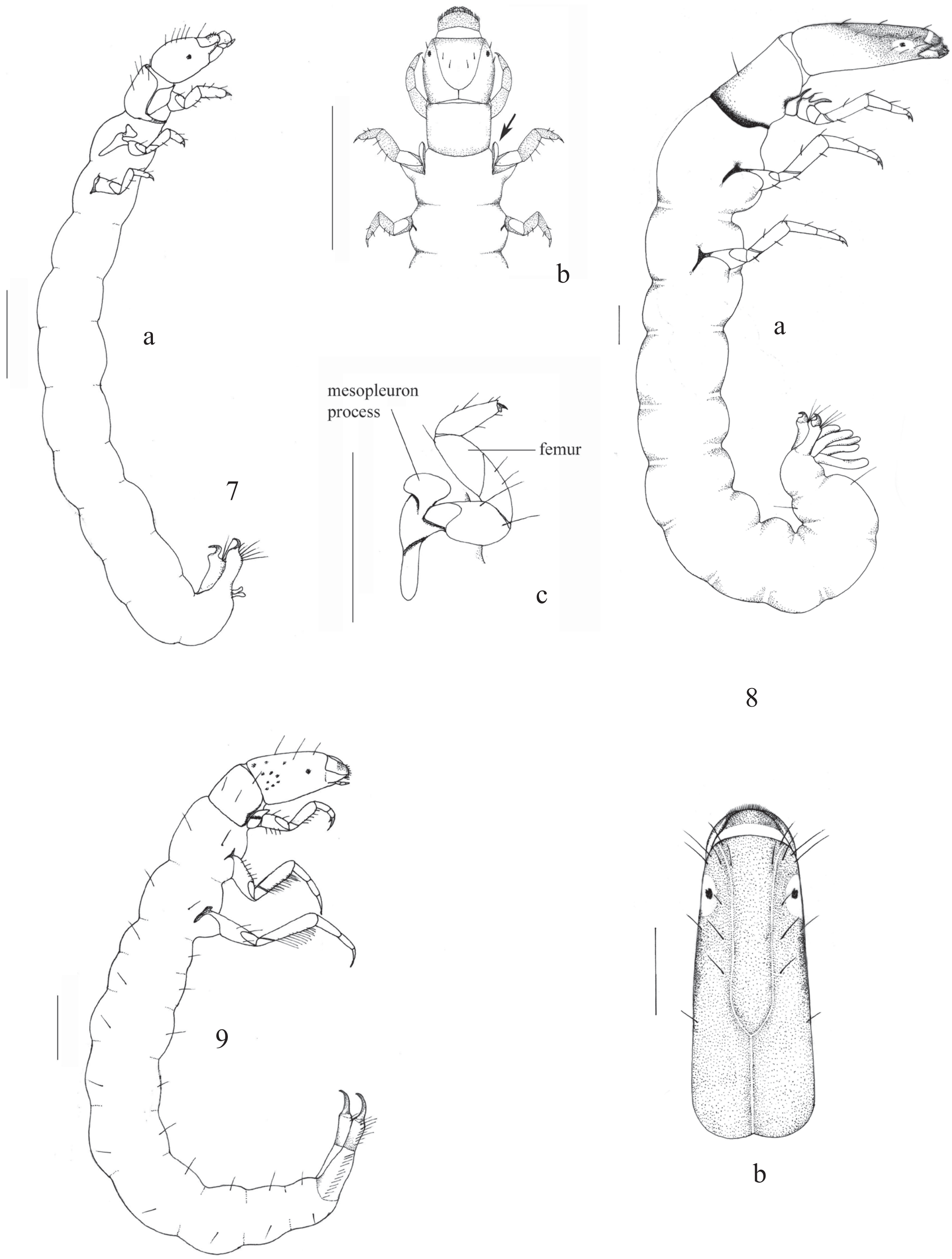


Fig. 7-9 7. Lateral view (a), dorsal view of head and thorax (b) and midleg (c) of *Melanotrichia* sp. larva (Xiphocentronidae); 8. Lateral view (a) and dorsal view of head (b) of *Stenopsyche siamensis* larva (Stenopsychidae); 9. Lateral view of Polycentropodidae larva.
Scale: (7a-b,8a-b,9)1 mm; (7c) 0.5 mm.

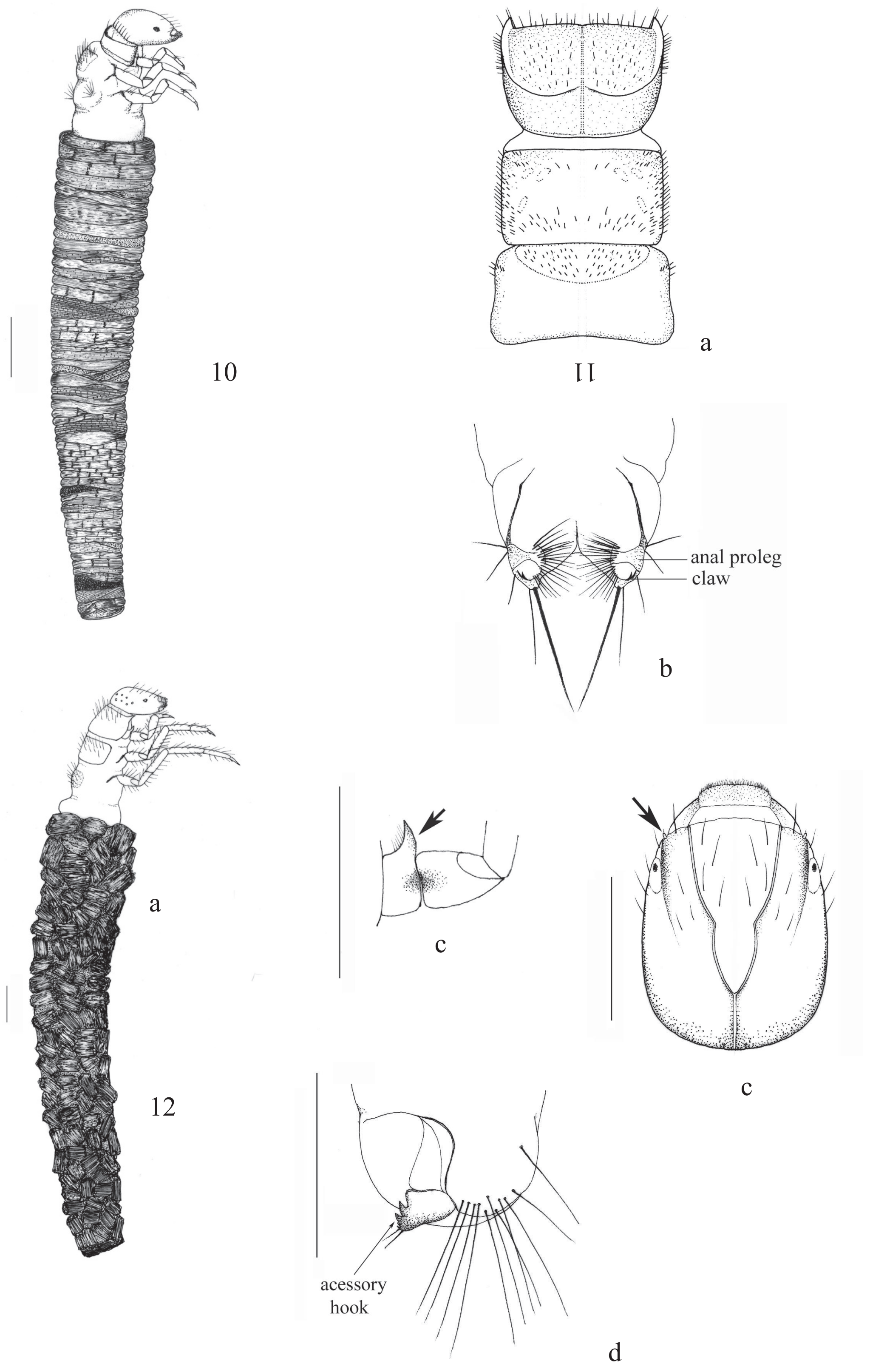


Fig. 10-12 10. Lateral view of *Micrasema* sp. larva (Brachycentridae); 11. Dorsal view of thorax (a) and ventral view of anal proleg (b) of Beraeidae (redrawn from Wiggins, 1996, fig. 13.1B-D); 12. Lateral view (a), trochantin (b), dorsal view of head (c) and lateral view of anal proleg (d) of Sericostomatidae larva Scale = 1 mm.

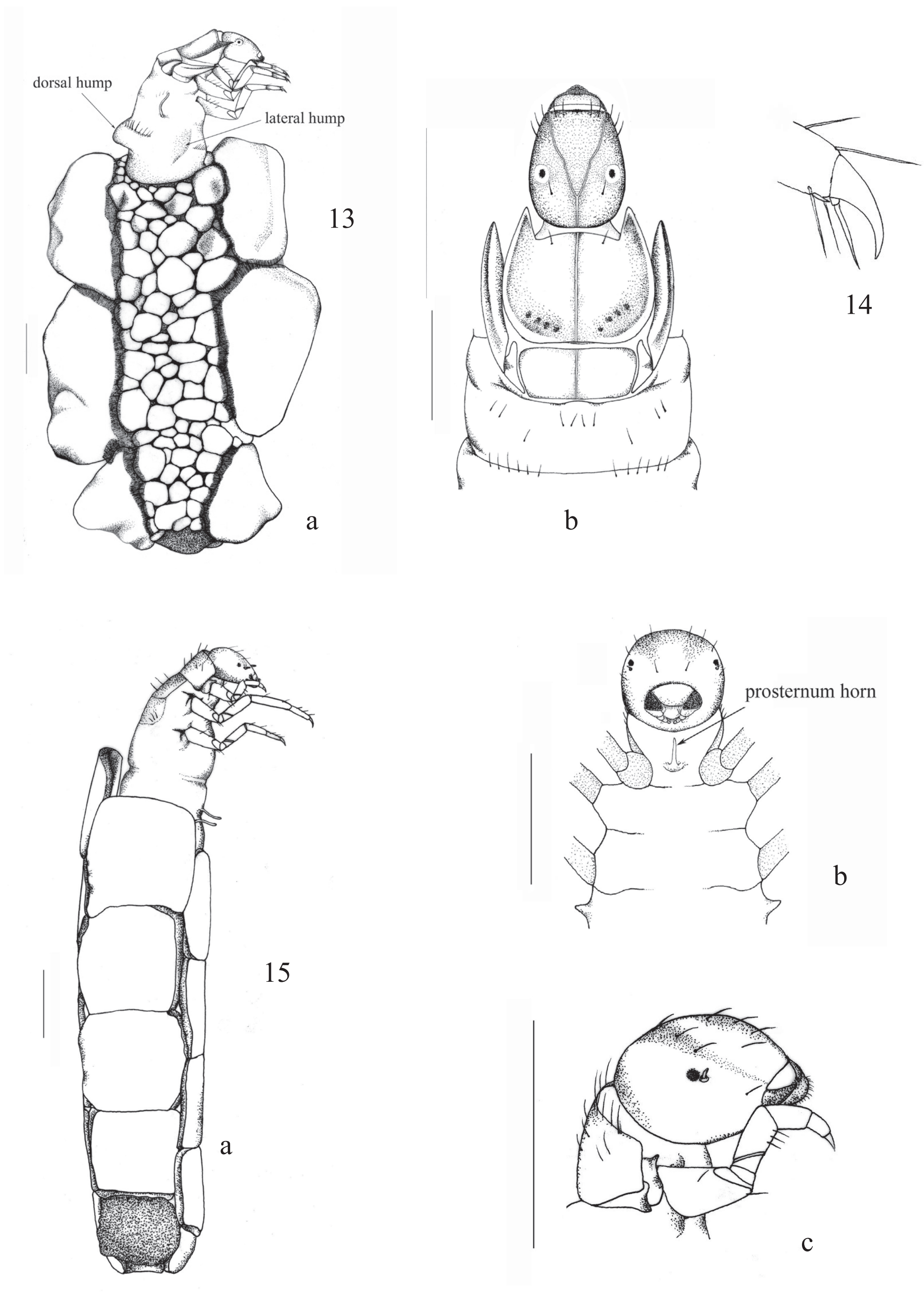


Fig. 13-15 13. Lateral view (a) and dorsal view of thorax (b) of *Goera* sp. larva (Goeridae);14. Tarsal claw of Apataniidae (redrawn from Wiggins, 1996, fig. 12.2A); 15. Lateral view larva (a), ventral view of head and thorax (b) and lateral view of head (c) of *Lepidostoma* sp. larva (Lepidostomatidae). Scale = 1 mm.

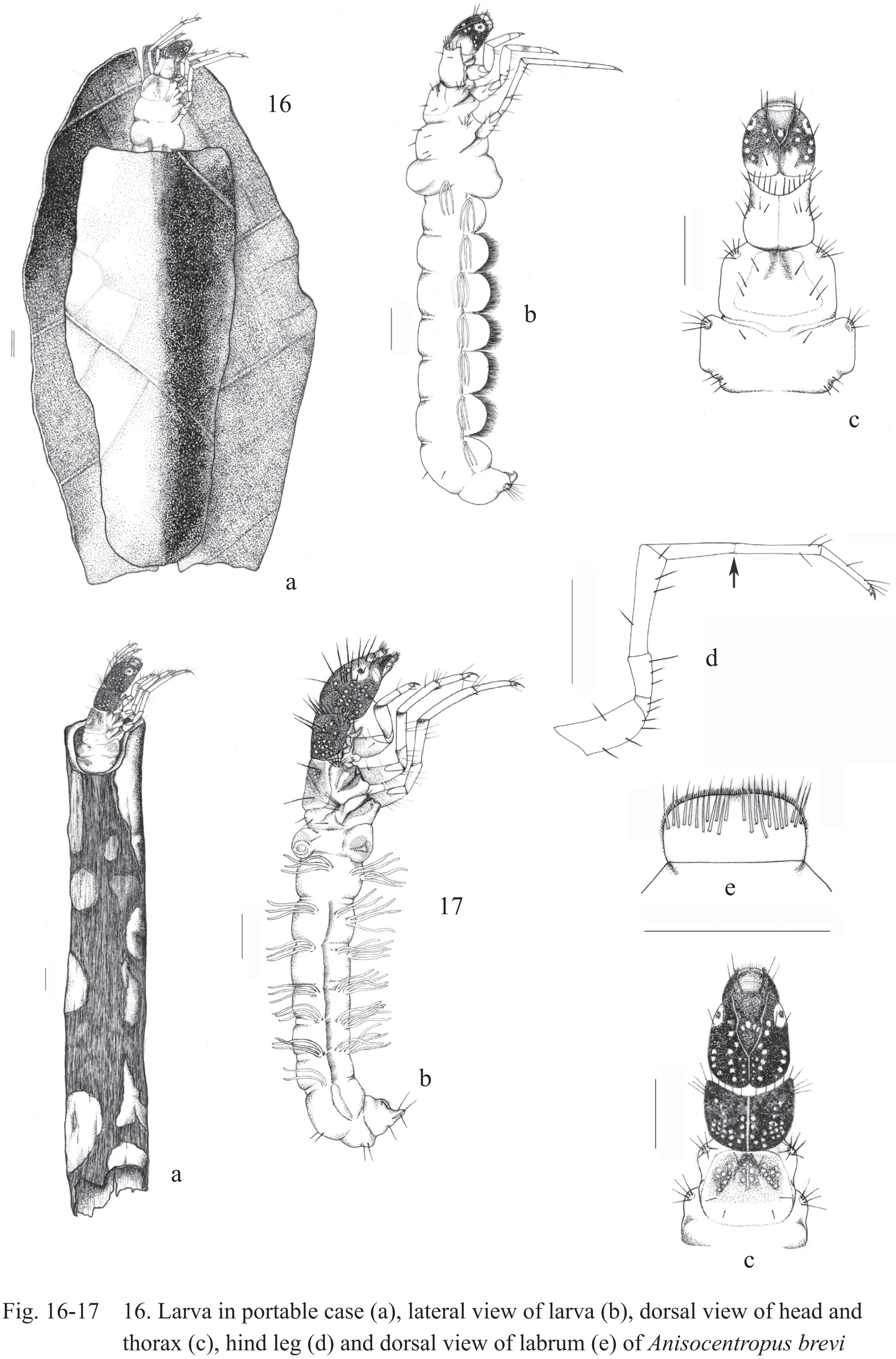


Fig. 16-17 16. Larva in portable case (a), lateral view of larva (b), dorsal view of head and thorax (c), hind leg (d) and dorsal view of labrum (e) of *Anisocentropus brevi* (Calamoceratidae); 17. Larva in portable case (a), lateral view of larva (b) and dorsal view of head and thorax (c) of *Ganonema extensum* (Calamoceratidae) Scale: (16a-c, 17a-c) 1 mm; (16d-e) 0.5 mm.

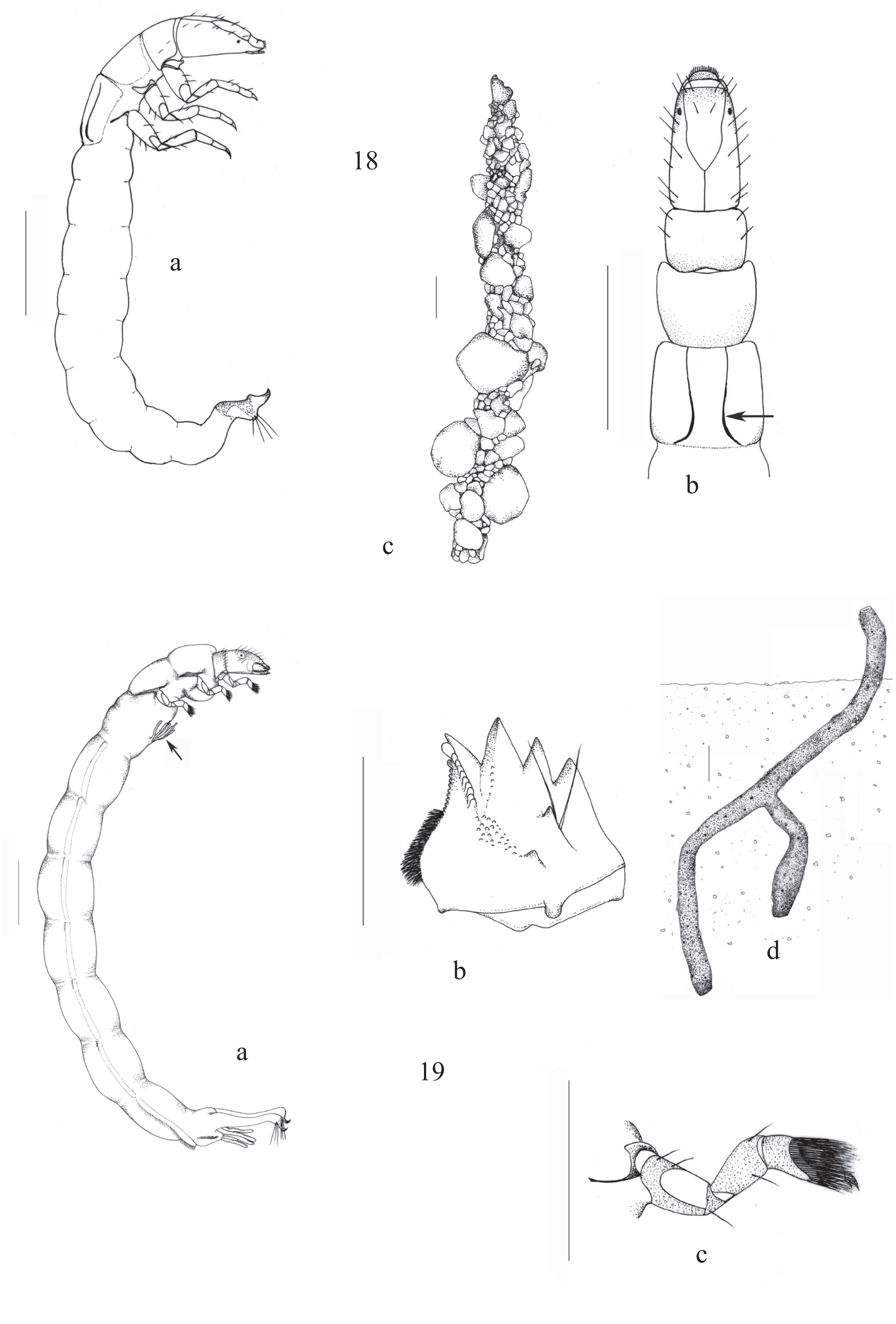


Fig. 18-19 18. Lateral view (a), dorsal view of head and thorax (b) and retreat (c) of *Pseudoneureclipsis* sp. larva (Dipseudopsidae); 19. Lateral view (a), dorsal view of right mandible (b), foreleg (c) and retreat (d) of *Dipseudopsis* sp. larva (Dipseudopsidae) .
Scale: (18c,19d) 2 mm; (18a-b,19a,19c) 1 mm; (19b) 0.5 mm.

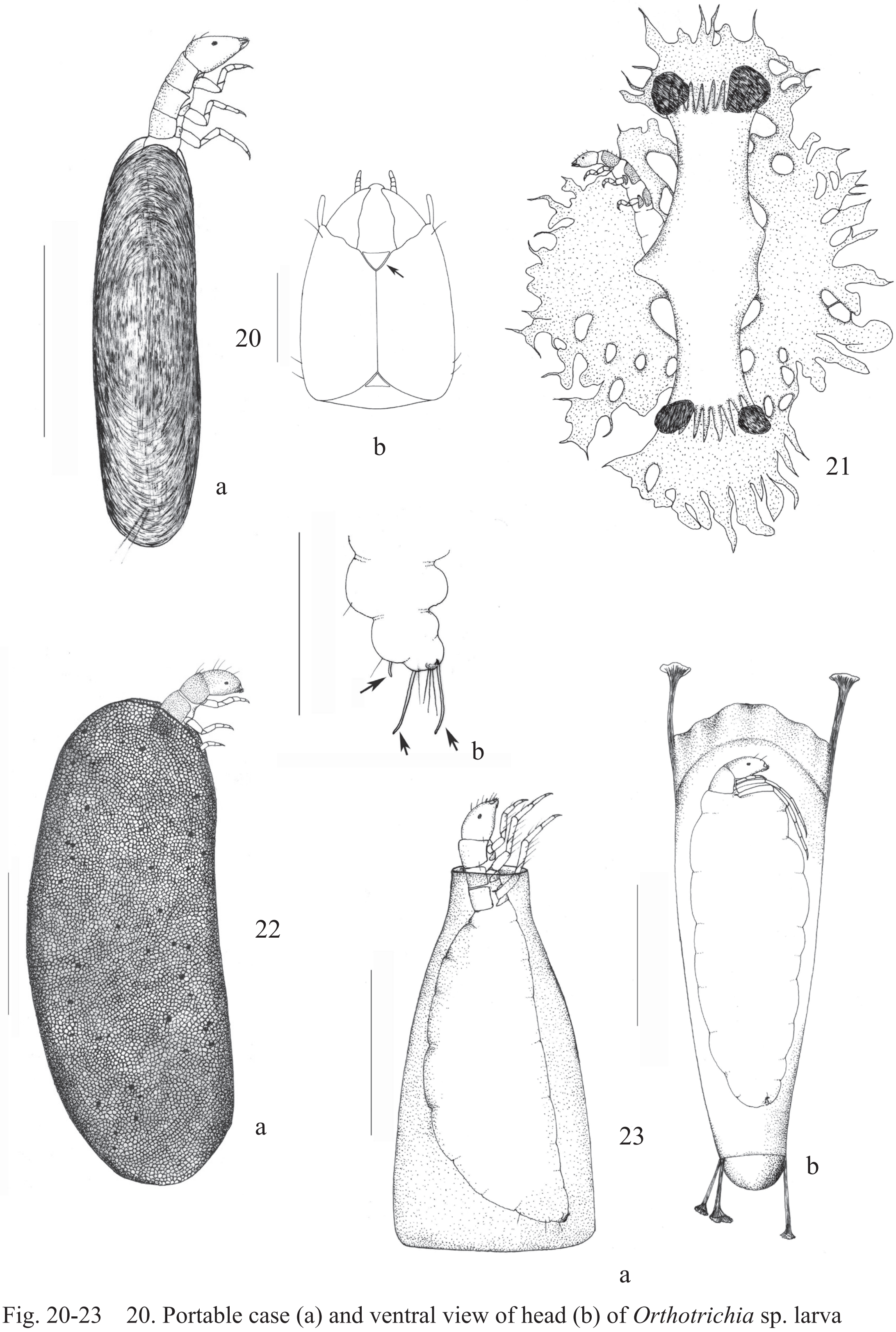
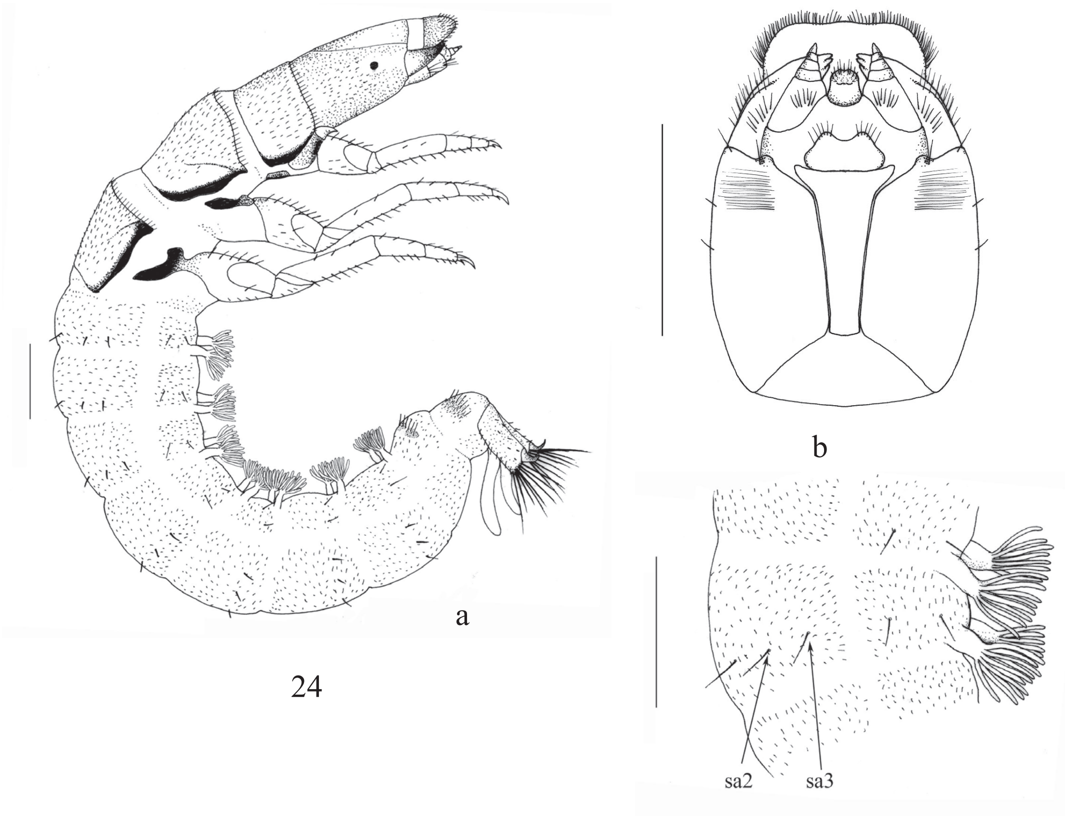


Fig. 20-23 20. Portable case (a) and ventral view of head (b) of *Orthotrichia* sp. larva (Hydroptilidae); 21. Fixed case of *Ugandatrichia* sp. larva (Hydroptilidae) (redrawn from Malicky, 1998, fig 5); 22. Portable case (a) and apical abdomen (b) of *Hydroptila* sp. larva (Hydroptilidae); 23. Portable case (a) and prepupa (b) of *Oxyethira* sp. larva (Hydroptilidae).
Scale: (20a,22a,23a-b) 1 mm; (20b,22b) 0.5 mm.



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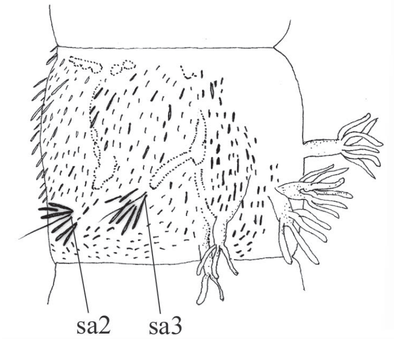

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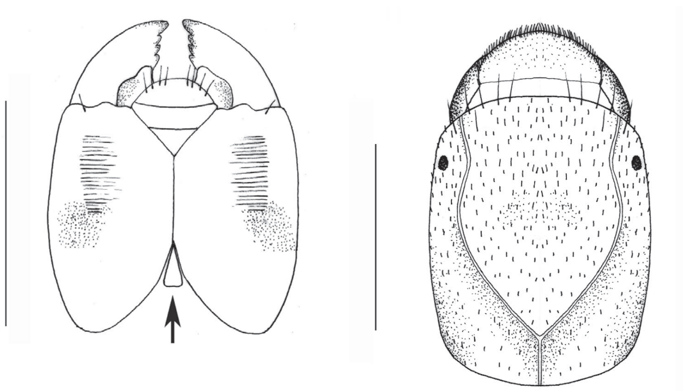

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Fig. 24-26 24. Lateral view (a), ventral view of head (b) and lateral of abdominal segment (c) of *Arctopsyche* sp. larva (Hydropsychidae); 25. Lateral view of abdominal segment of *Parapsyche* sp. larva (redrawn from Wiggins, 1996, fig. 7.8B); 26. Ventral view (a) and dorsal view (b) of head of *Diplectrona* sp. larva (Hydropsychidae).
Scale = 1 mm.

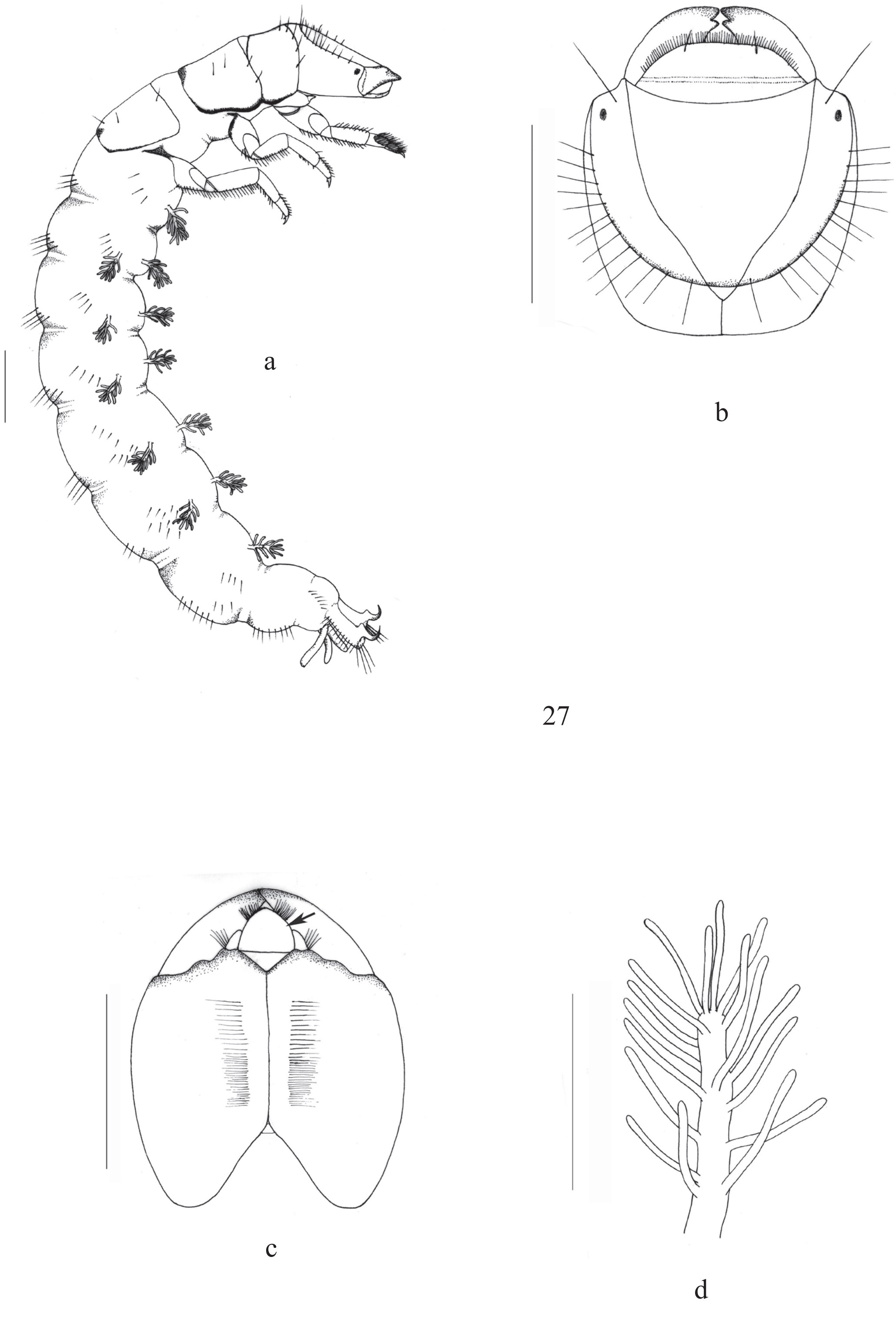


Fig. 27 27. Lateral view (a), dorsal view of head (b) and ventral view of head (c) and gill (d) of *Macrostemum* sp. larva (Hydropsychidae).
Scale: (7a-b,7d) 1 mm; (27c) 0.5 mm.

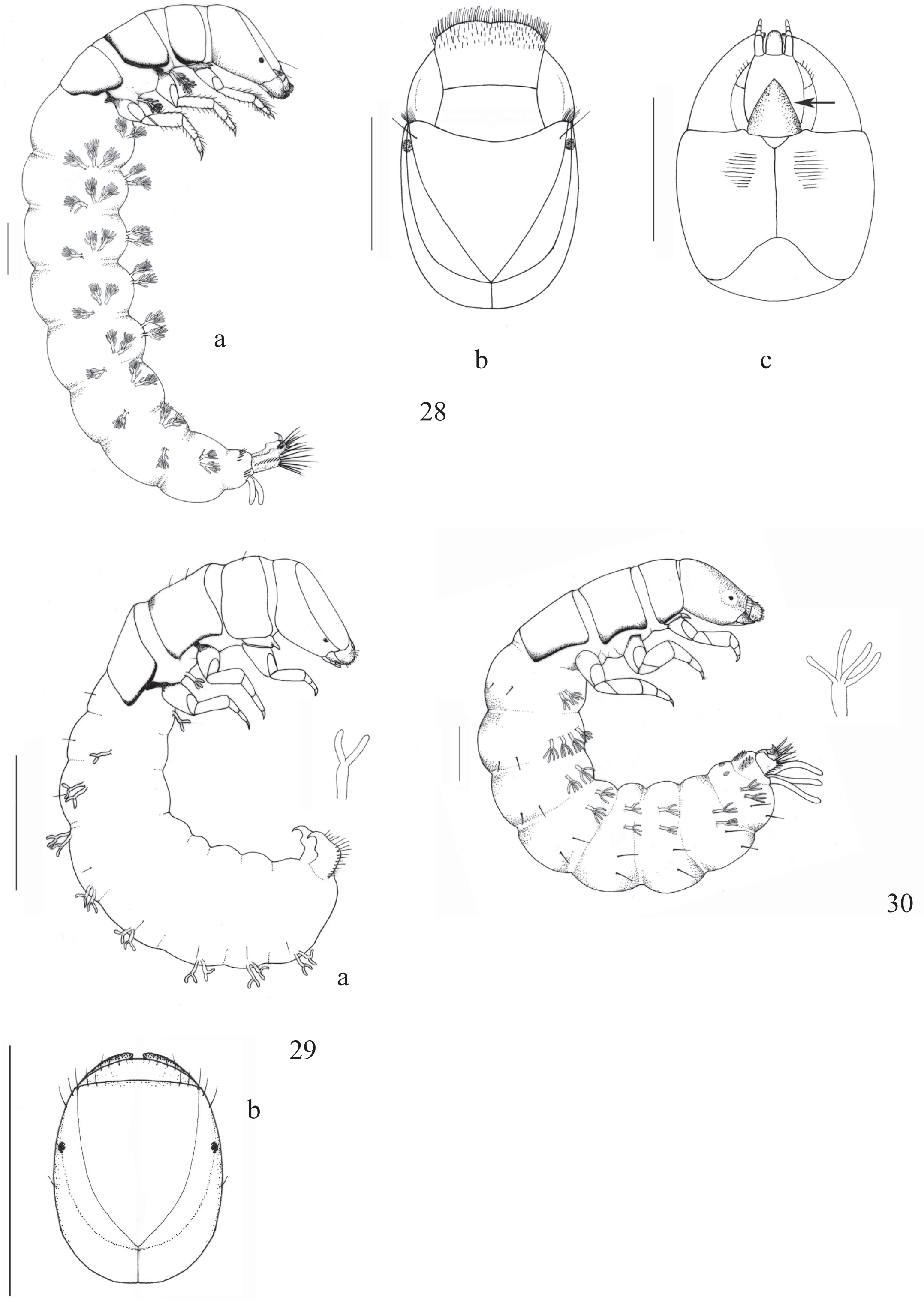


Fig. 28-30 28. Lateral view (a), dorsal view of head (b) and ventral view of head (c) of *Amphipsyche* sp. larva (Hydropsychidae); 29. Lateral view (a) and dorsal view of head (b) of *Pseudoleptonema supalak* larva (Hydropsychidae); 30. Lateral view of *Trichomacronema* sp. larva (Hydropsychidae).
Scale = 1 mm.

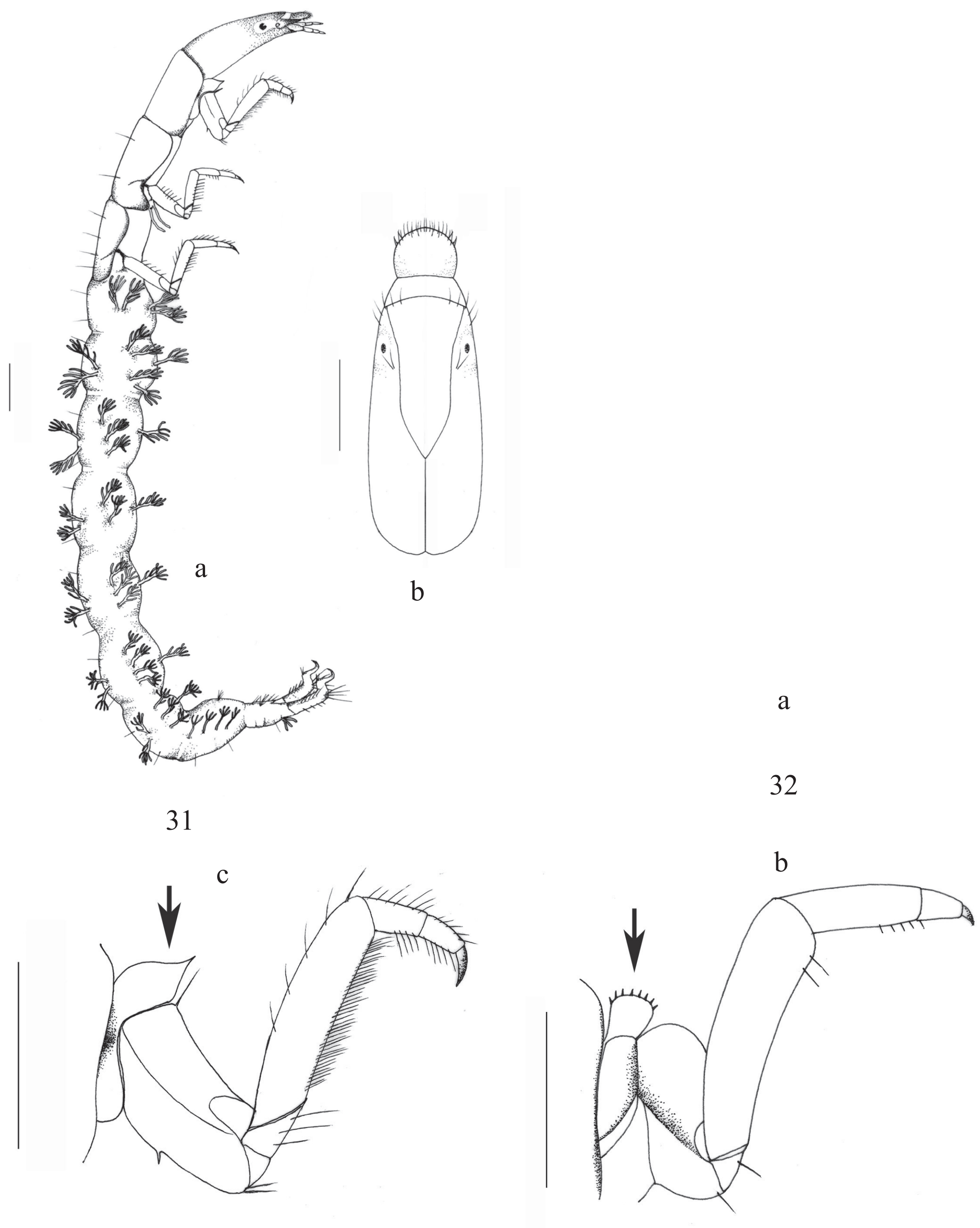


Fig. 31-32 31. Lateral view (a), dorsal view of head (b) and right trochantin (c) of *Polymorphanisus* sp. larva (Hydropsychidae); 32. Lateral view (a) and right trochantin (b) of *Oestropsyche* sp. larva (Hydropsychidae).
Scale = 1 mm.

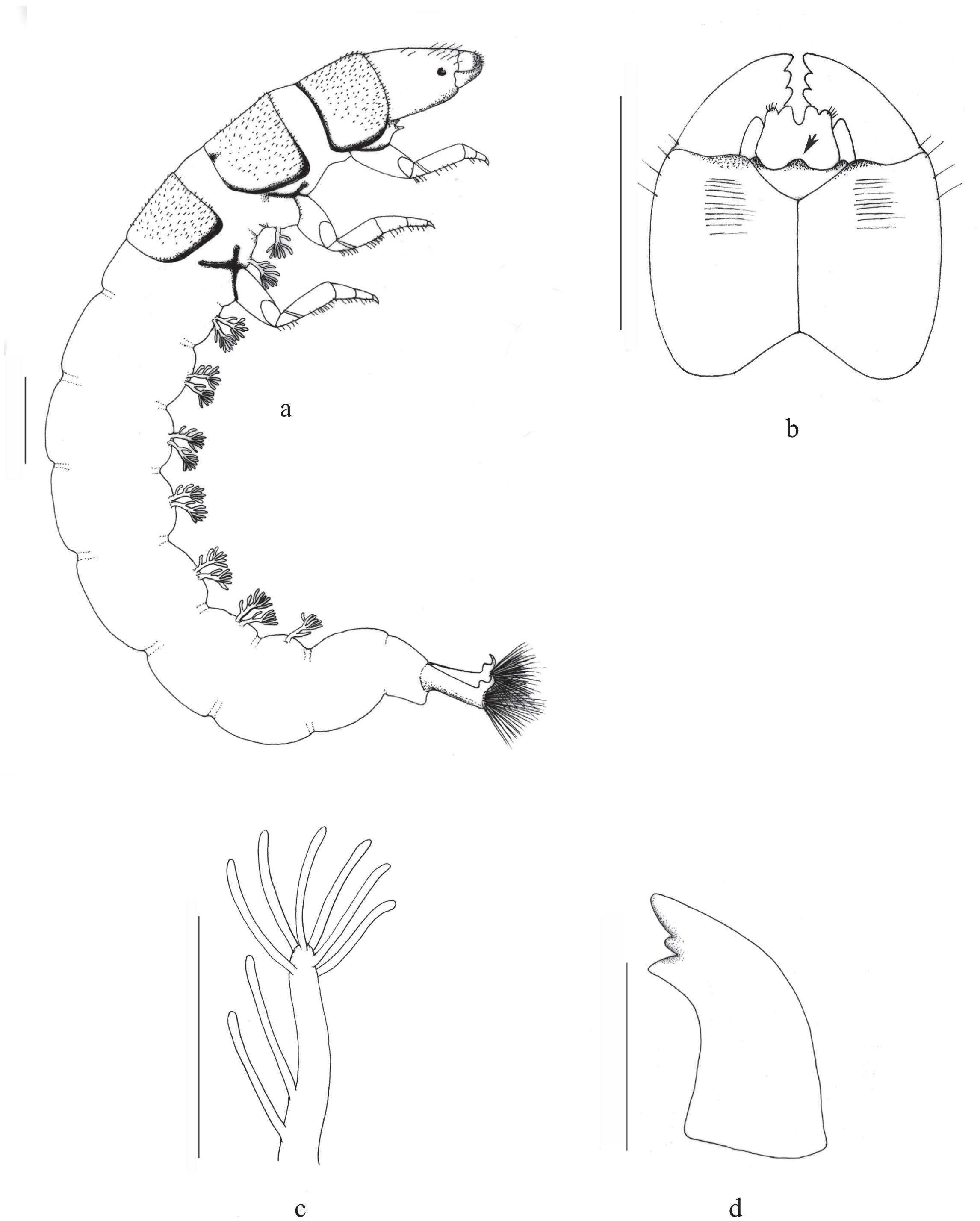


Fig. 33 Lateral view (a), ventral view of head (b), gill (c) and dorsal view of right mandible (d) of *Potamyia* sp. larva (Hydropsychidae).
Scale = 1 mm.

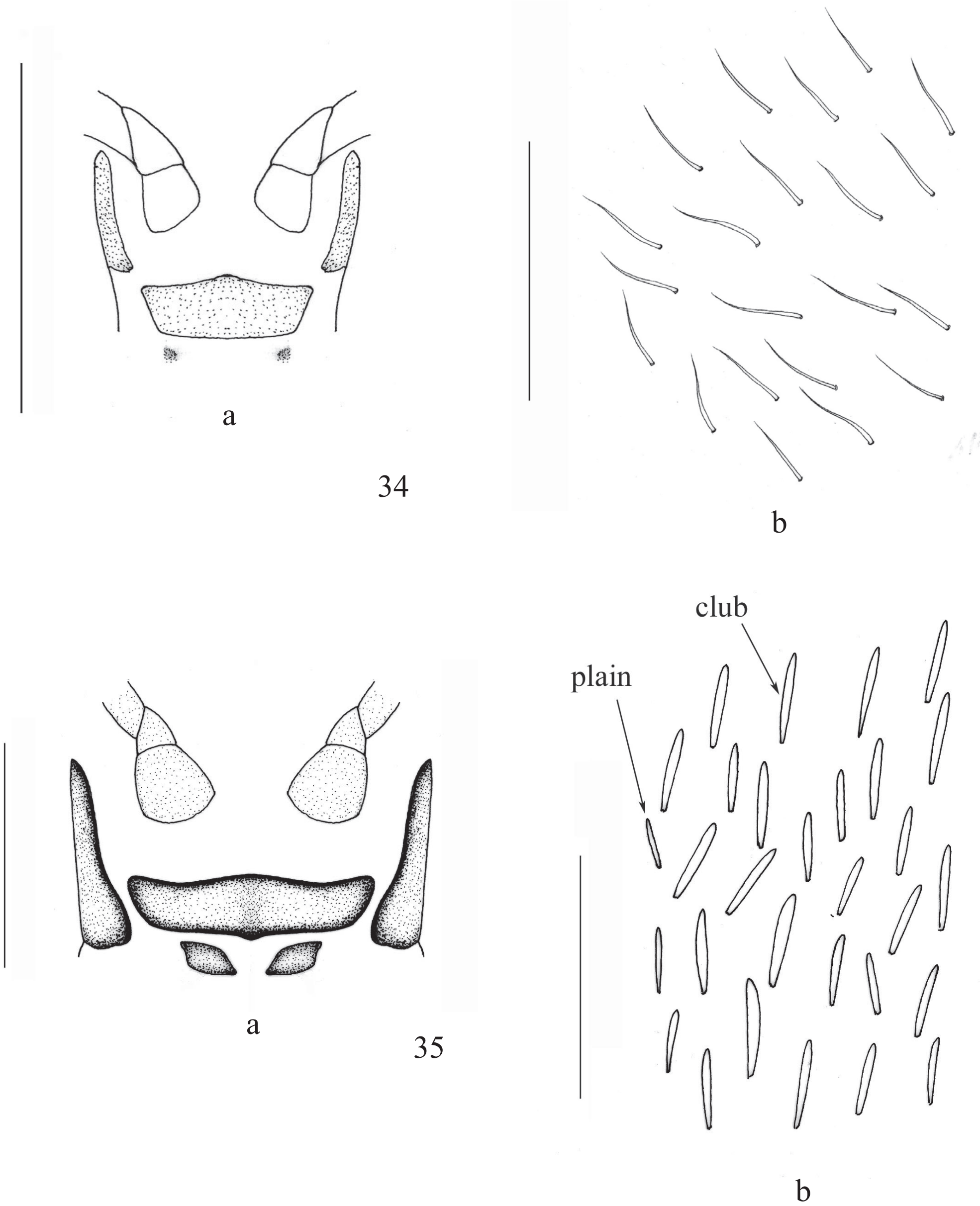


Fig. 34-35 34. Ventral view of prosternum (a) and detail of setation on abdominal tergum (b) of *Cheumatopsyche* sp. larva (Hydropsychidae); 35. Ventral view of prosternum (a) and detail of setation on abdominal tergum (b) of *Ceratopsyche* sp. larva (Hydropsychidae).
Scale: (34a, 35a) 1 mm; (34b, 35c) 0.1 mm.

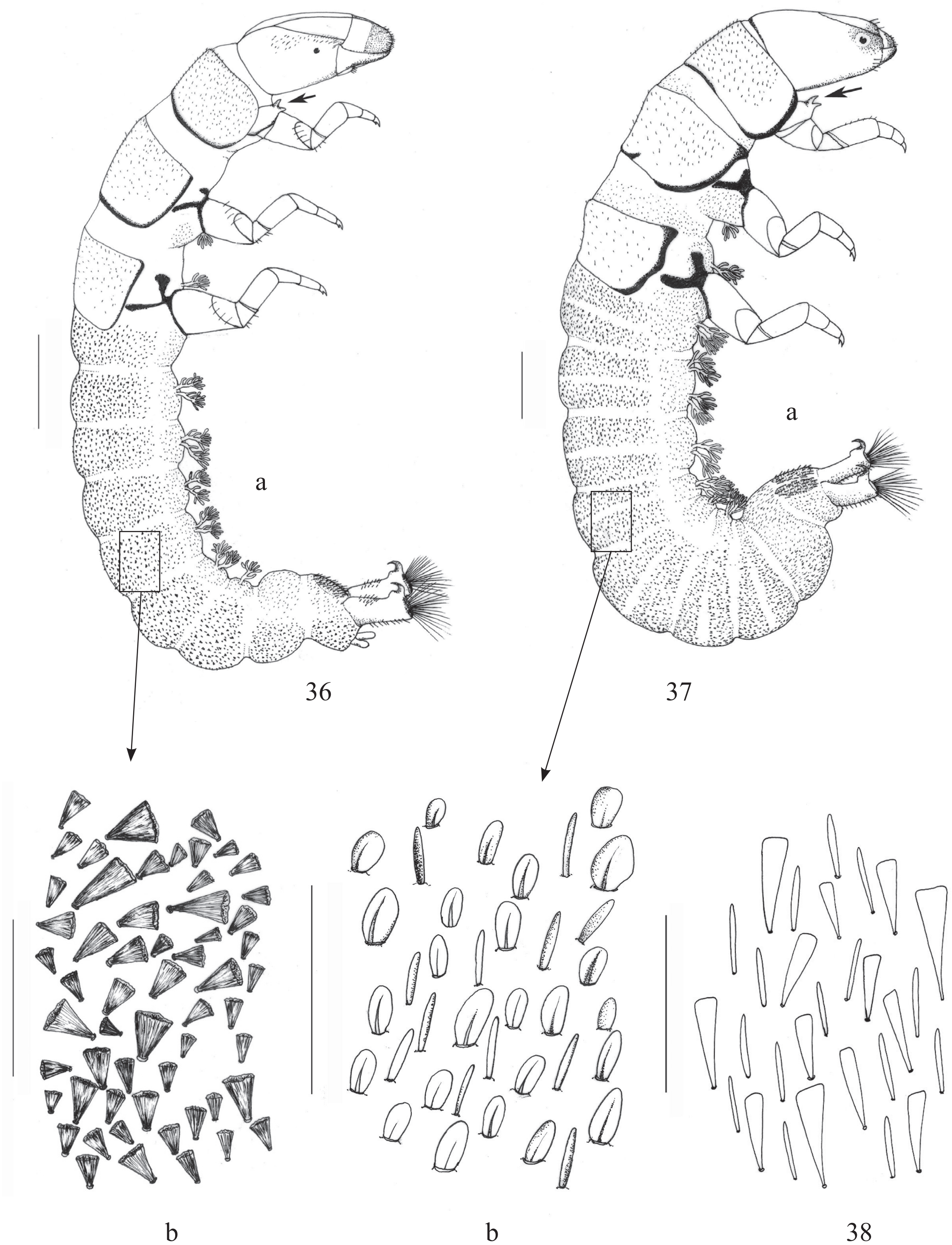


Fig. 36-38 36. Lateral view (a) and detail of setation on abdominal tergum (b) of *Hydatomanicus* sp. larva (Hydropsychidae); 37. Lateral view of larva (a) and detail of setation on abdominal tergum (b) of *Hydromanicus* sp. larva (Hydropsychidae); 38. Detail of setation on abdominal tergum of *Hydrosyche* sp. larva (Hydropsychidae).
Scale: (36a, 37b) 1 mm; (36b, 37b, 38) 0.1 mm.

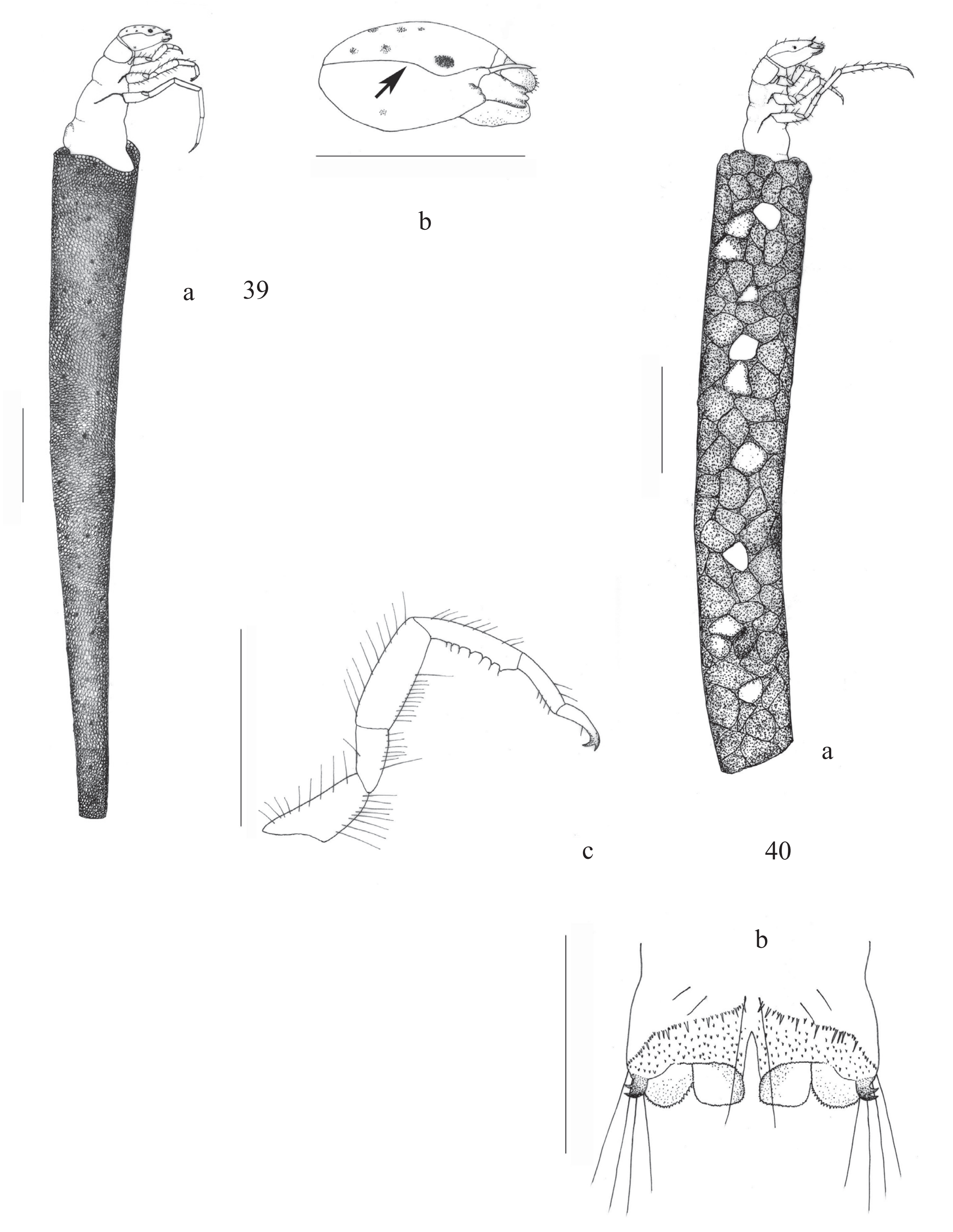


Fig. 39-40 39. Portable case (a), lateral view of head (b) and midleg (c) of *Leptocerus* sp. larva (Leptoceridae); 40. Portable case (a) and ventral view of anal proleg (b) of *Setodes* sp. larva (Leptoceridae).
Scale (39a-b, 40a-b) 1 mm; (39c) 0.5 mm.

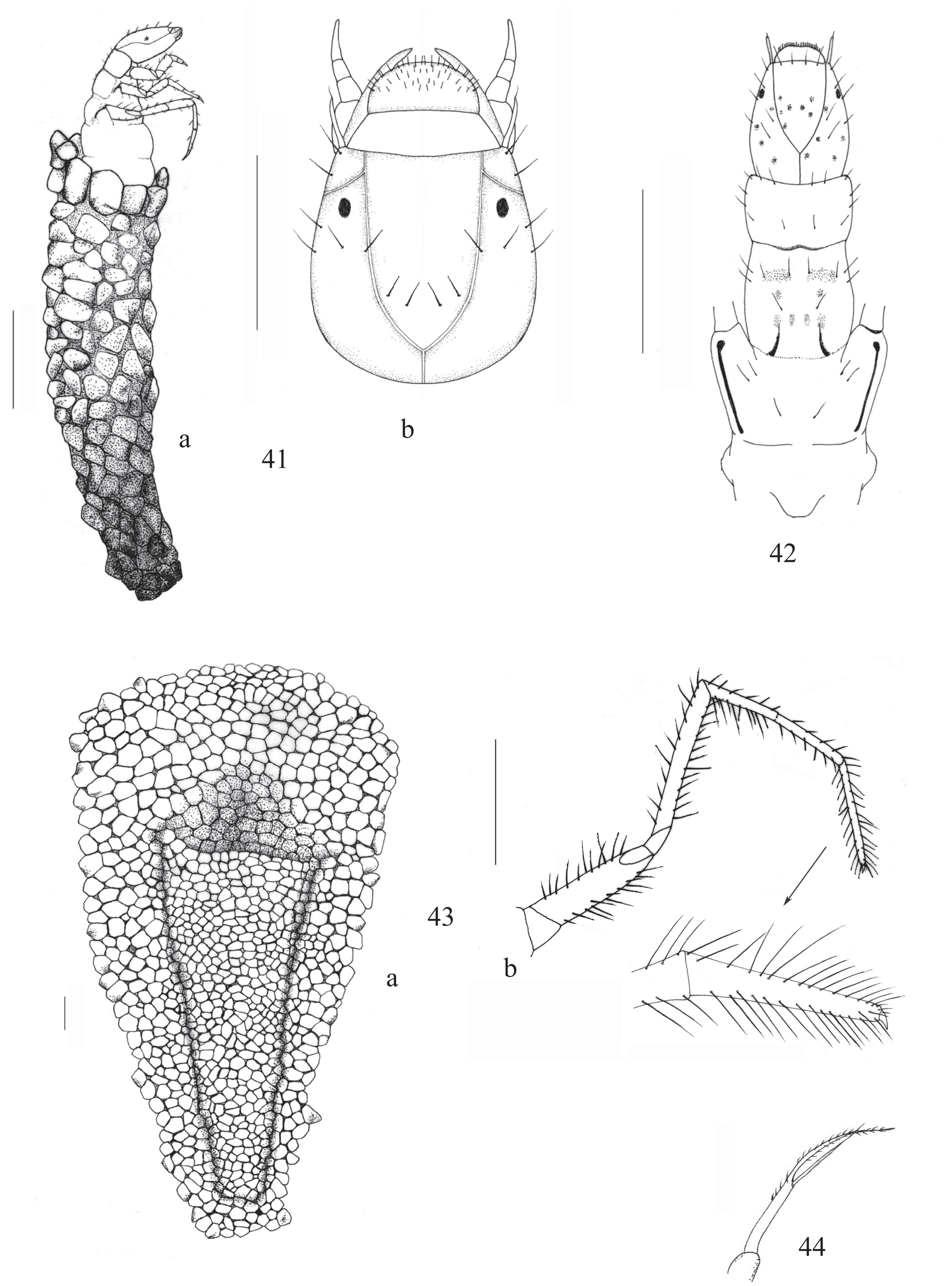


Fig. 41-44 41. Portable case (a) and dorsal view of head (b) of *Oecetis* sp. larva (Leptoceridae); 42**.** Dorsal view of head and thorax of *Ceraclea* sp. larva (Leptoceridae); 43**.** Ventral view of portable case (a) and hindleg (b) of *Molanna* sp. larva (Molannidae); 44**.** Tarsal claw of hindleg of *Molannodes* sp. larva (Molannidae) (redrawn from Wiggins, 1996, fig. 21.2A).
Scale: (41a, 42, 43a-b) 1 mm, (41b) 0.5 mm.

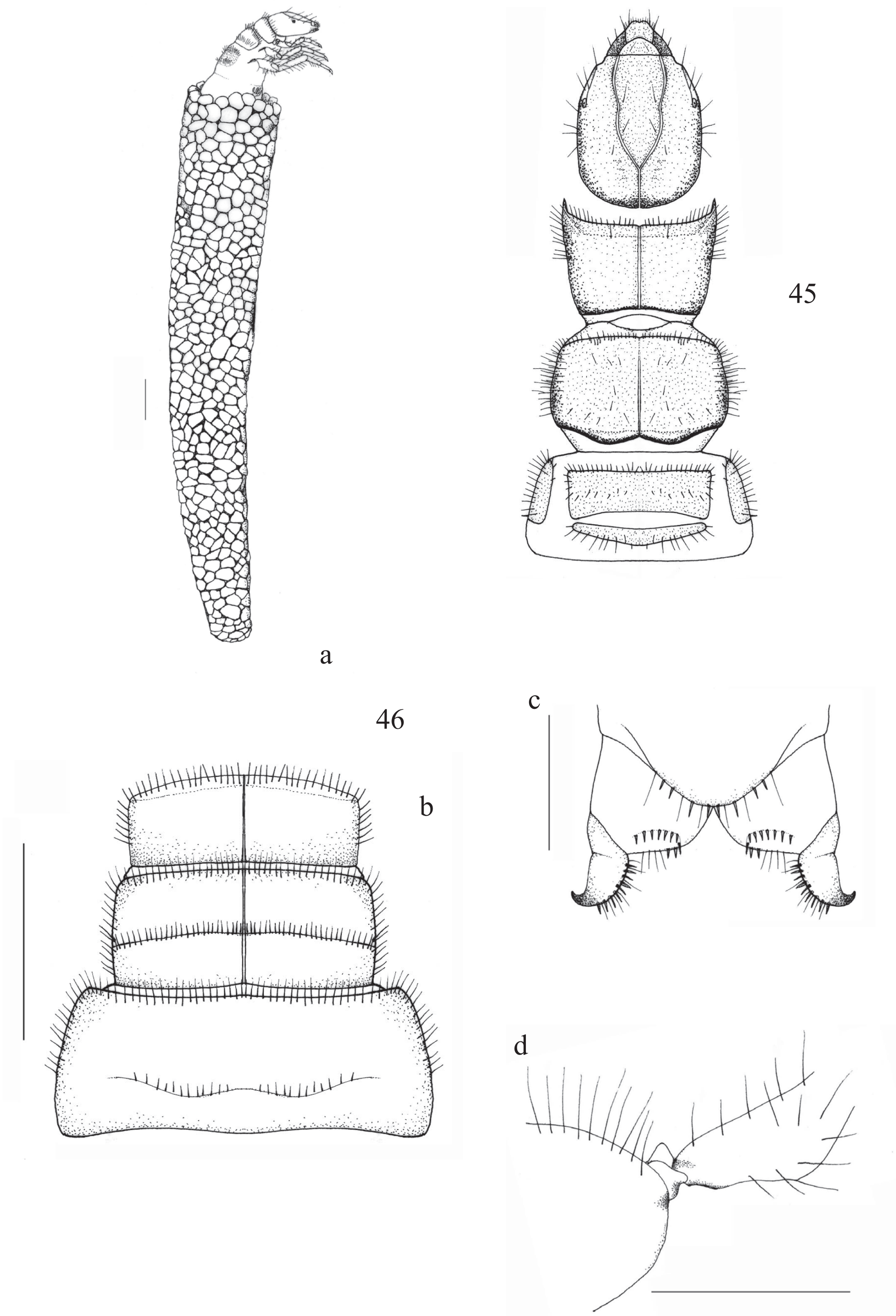
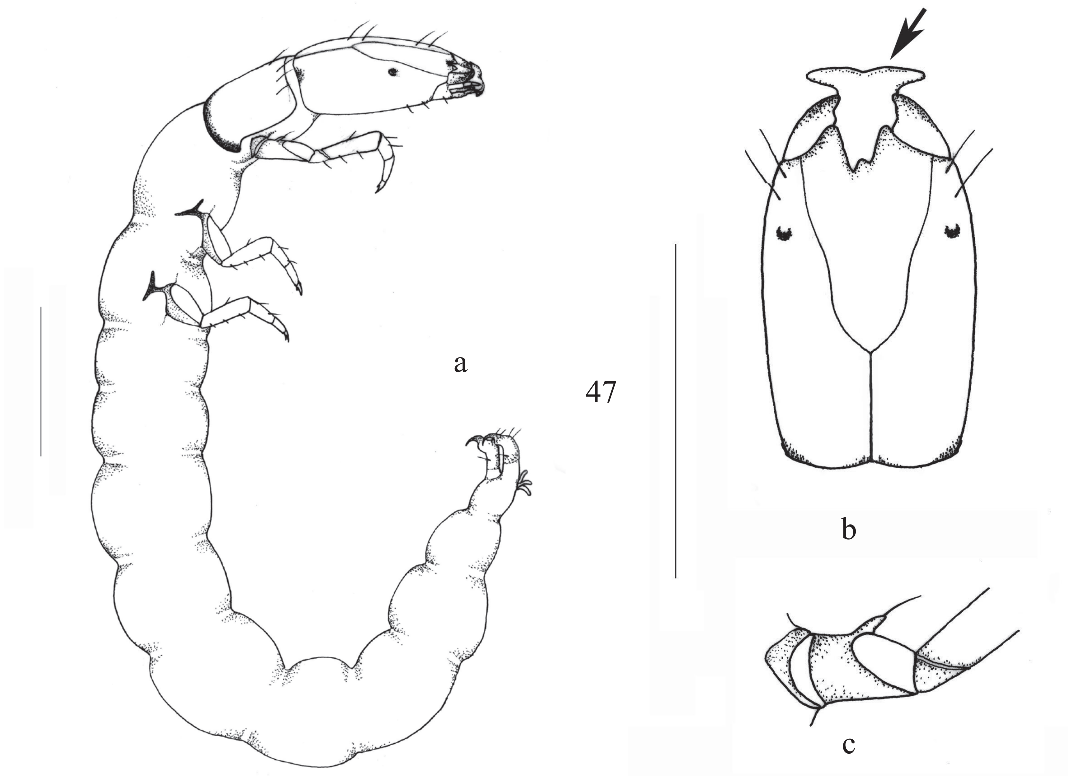
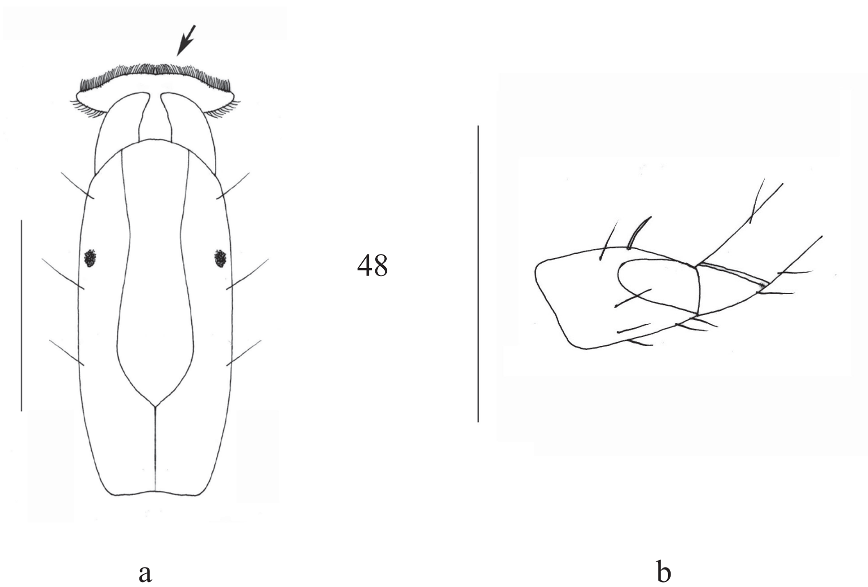


Fig. 45-46 45. Dorsal view of head and thorax of *Psilotreta* sp. larva (Odontoceridae) (redrawn from Wiggins, 1996, fig. 22.6); 46. Portable case (a), dorsal view of thorax (b), dorsal view of anal proleg (c) and trochantin (d) of *Marilia* sp. larva (Odontoceridae).
Scale: (46a-c) 1 mm, (46d) 0.5 mm.





a b

Fig. 47-48 47. Lateral view (a) and dorsal view of head (b) and foreleg (c) of *Chimarra* sp. larva (Philopotamidae); 48. Dorsal view of head (a) and foreleg (b) of *Wormaldia* sp. larva (Philopotamidae).
Scale: (47a) 1 mm; (47b-c,48a-b) 0.5 mm.

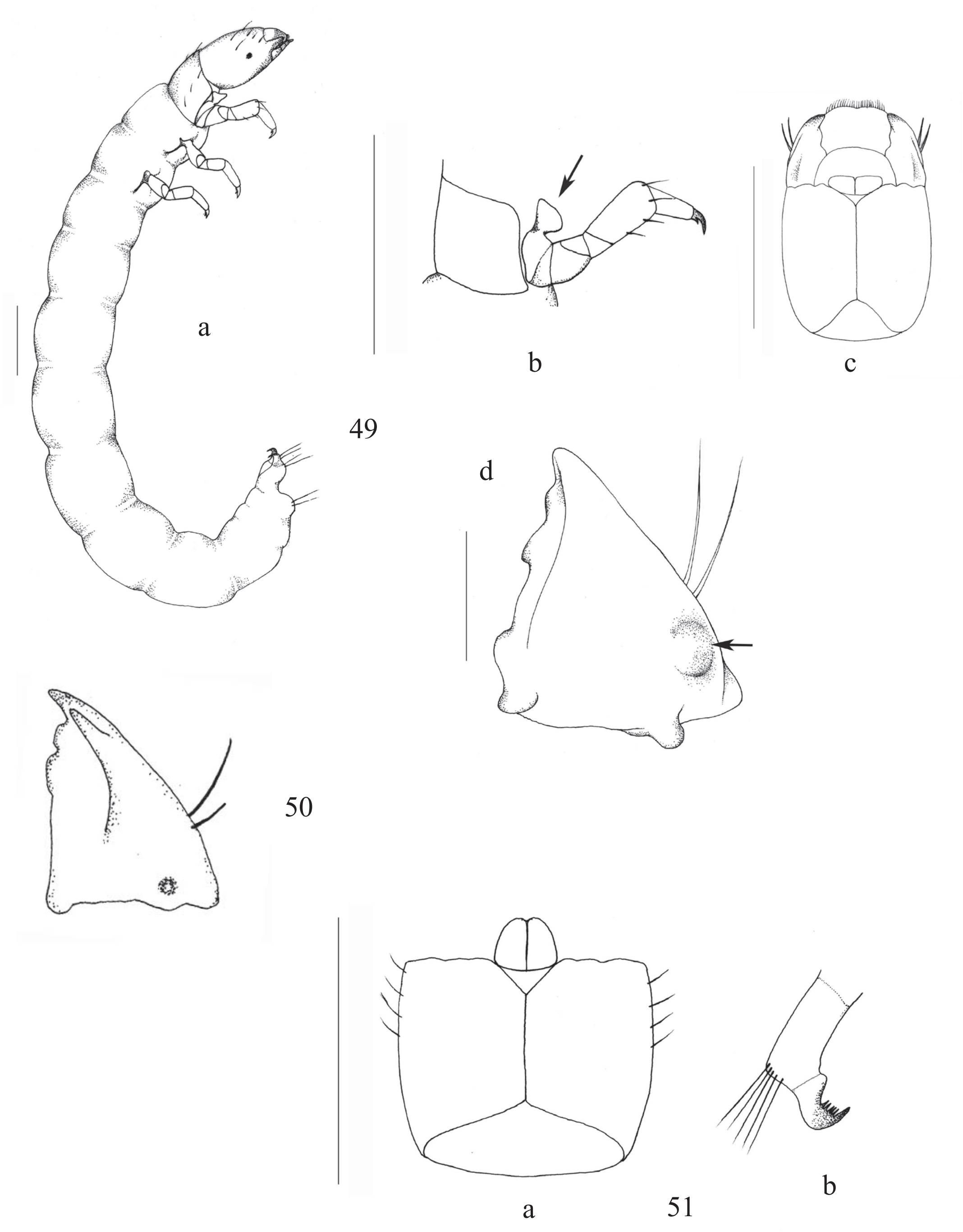


Fig. 49-51 49. Lateral view (a), foreleg (b), ventral view of head (c) and dorsal view of right mandible (d) of *Tinodes* sp. larva (Psychomyiidae); 50. Dorsal view of right mandible of *Lype* sp. larva (Psychomyiidae) (redrawn from Wiggins, 1996, fig. 10.1c); 51. Ventral view of head (a) and anal hook (b) of *Psychomyia* sp. larva (Psychomyiidae).
Scale: (49a-b) 1 mm; (49c-d,51a-b) 0.5 mm.

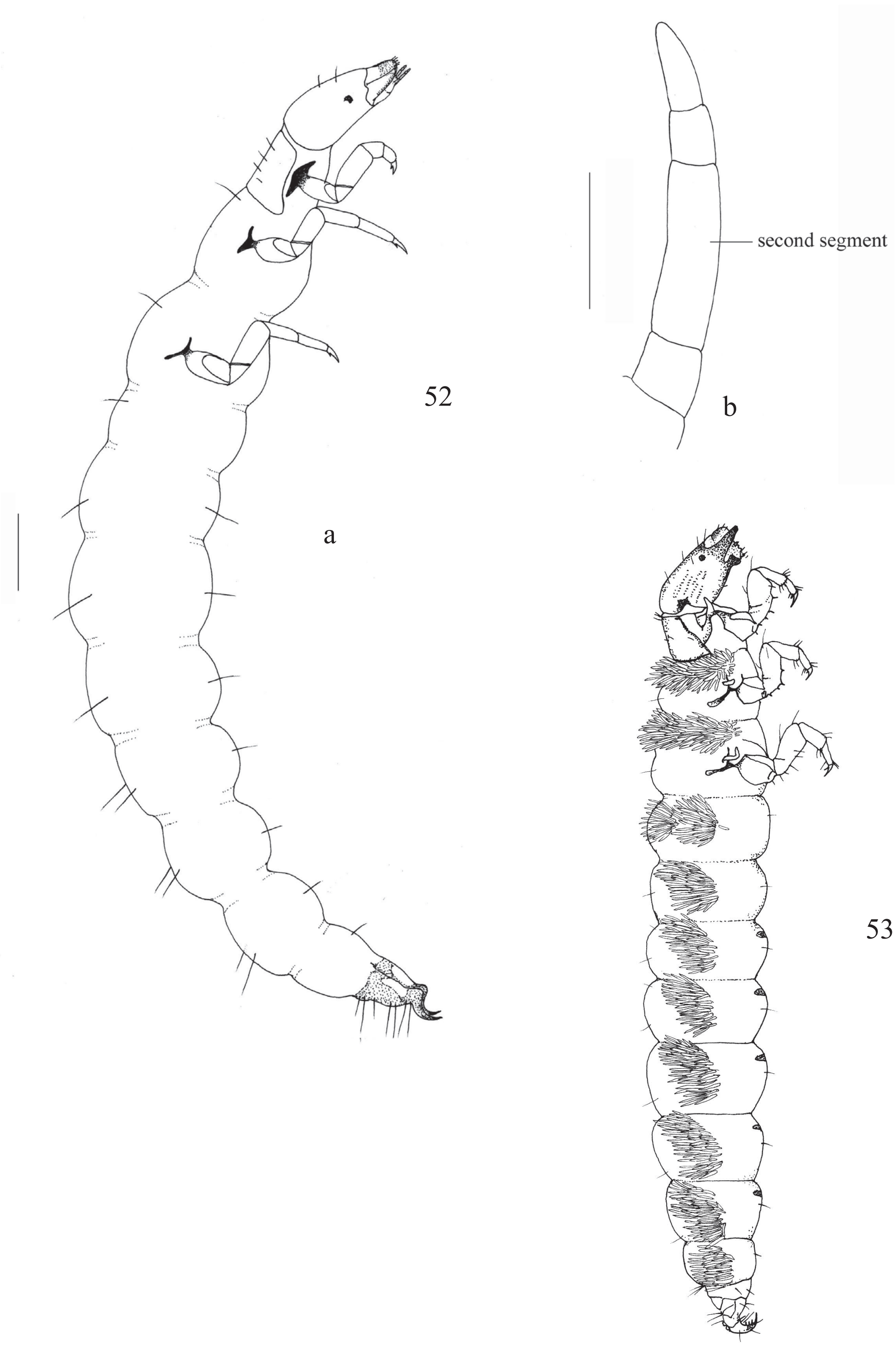


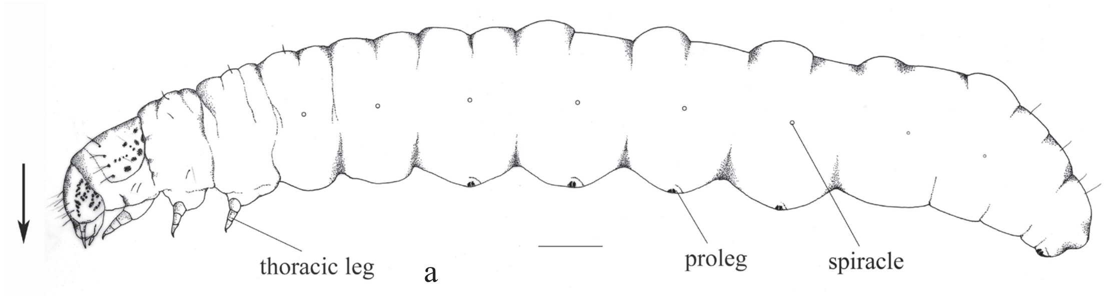
Fig. 52-53 52. Lateral view (a) and maxillary palp (b) of *Rhyacophila* sp. larva (Rhyacophylidae); 53. Lateral view of *Himalopsyche* sp. larva (Rhyacophylidae) (redrawn from Wiggins, 1996, fig. 4.1A). Scale: (52a) 1 mm; (52b) 0.5 mm.

Chapter 22 Order Lepidoptera

True aquatic moths belong to the family Crambidae in Lepidoptera. Many lentic species are stem borers of rice in paddy fields. Little attention is given to lotic lepidopterans. The caterpillar has prolegs on the ventral of abdominal segments. Five genera are common in lotic habitats. *Eoophyla* larvae construct and live in tents that are fastened to rock surfaces in fast flowing streams. Larvae use hook-like crochets on the prolegs to attach to rock surfaces and move in the lateral direction. They feed on diatoms and algae. *Paracymoriza* and *Potamomusa* larvae feed on leaves. *Eophila* larvae cut leaves into two small pieces and glue them together with silk to make portable shelters. The larva feeds on leaves of water lilies and attaches its shelter to the surface of a leaf for pupation. Yoshiyasu (1985: cited in Habeck and Solis, 1994) has provided useful information on and illustrations of larvae of the Nymphulinae and the Musotiminae of Japan. A key to the five common genera of Crambidae larvae is provided.

Key to Genera of Aquatic Lepidoptera (Crambidae) Larvae of Indochina

1	Thorax and abdomen with gills	2
1′	Thorax and abdomen without gills (Fig. 1a); larvae live in portable retreats made of leaves or leaf pieces (Fig. 1b)	*Elophila*
2(1)	Head flattened dorsally, prognathous (Fig. 2); mandibles prominent; gill tufts on lateral side of body; larva lives under a silken tent-like retreat on a rock in riffle areas	*Eoophyla*
2′	Head rounded, hypognathous (Fig. 1, 3, 4, 5); mandibles not visible dorsally; gills vary	3
3(2′)	With branched or unbranched supraspiracular and subspiracular gills (Fig. 3); larvae in portable retreats constructed of aquatic plant material	*Parapoynx*
3′	With unbranched gills usually arising separately	4
4(3′)	With gills on thoracic segment I (Fig. 4)	*Potamomusa*
4′	Without gills on thoracic segment I (Fig. 5)	*Paracymoriza*



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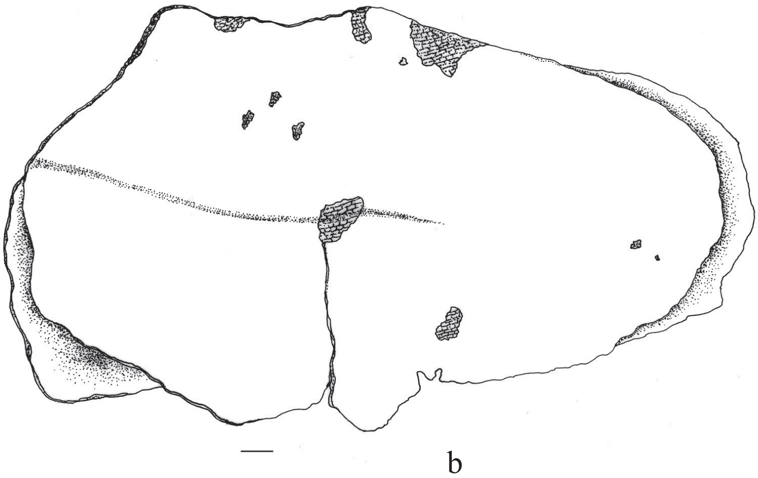

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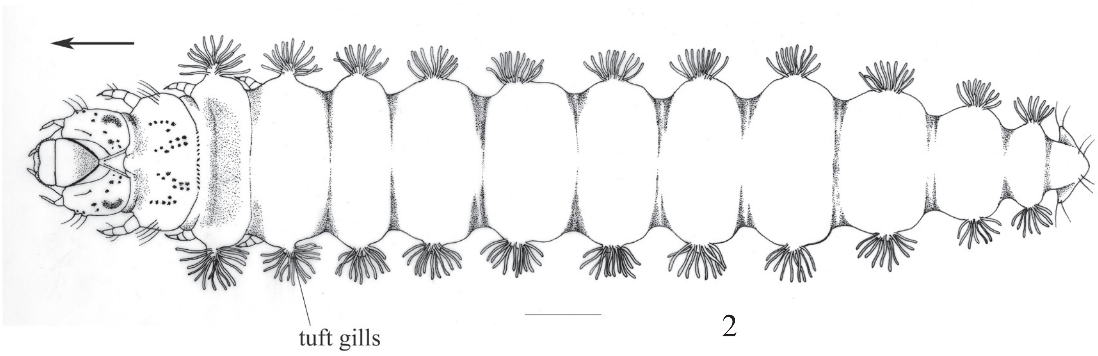


Fig. 1-2: 1. Lateral view (a) and portable retreat (b) of *Elophila* sp. larva; 2. Dorsal view of larva of *Eoophyla* sp. (↓ head hypognathus, ← head prognathous)
Scale = 1 mm.

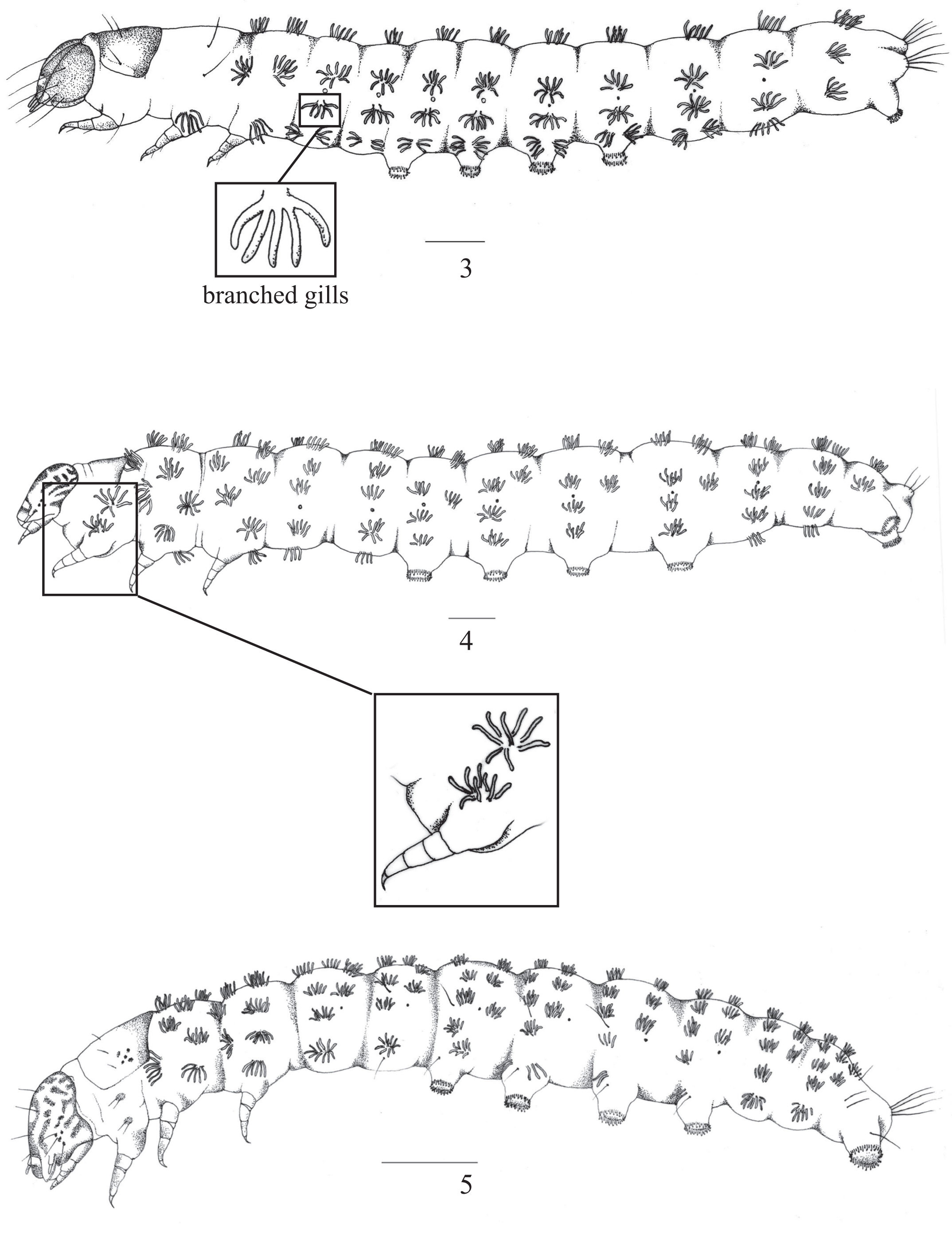


Fig. 3-5: 3. Lateral view of *Parapoynx* sp. larva; 4. Lateral view of *Potamomusa* sp. larva; 5. Lateral view of *Paracymoriza* sp. larva.
Scale = 1 mm.

Chapter 23 Order Coleoptera

The Coleoptera, or beetles, has approximately 250,000 known species globally (Lawrence *et al*., 1999) and approximately 5,000 species are aquatic and semiaquatic. Two of four suborders and a total of 18 families are aquatic and semiaquatic. Most true aquatic beetle larvae live in water and may be aquatic or terrestrial as adults. Hydraenidae and Dryopidae have aquatic adults and terrestrial larvae. Research on Asian coleopterans is cited in Nilsson (1995), Balke & Hendrick (1997), Hendrick & Balke (1997) and Dudgeon (1995a, 1995b). The 'China Water Beetle Survey' was established in 1992, and it increased the knowledge of the 18 aquatic and semiaquatic beetle families of China (see details in Jäch & Ji (eds.), 1995). It is currently impossible to identify larvae to genus and species. The following keys to families of adult and larval stages of aquatic Coleoptera of Indochina are modified from those of White and Brigham (1996).

Key to Families of Aquatic Coleoptera Adults of Indochina

1 Hind coxae enlarged as broad flattened plates, completely covering 2 or 3 basal abdominal segments (Fig. 1) .... Halipidae
1′ Hind coxae sometimes extended posteriorly but not as broad flattened plates 2

2(1′) Head with two pairs of compound eyes, dorsal and ventral pairs (Fig. 2a-b); meso- and metathoracic legs modified to short flat oar-like structures (adults move in little circle upon surface of the water) .... Gyrinidae
2′ Head with 1 pair of compound eyes; meso-and metathoracic legs long 3

3(2′) Head anteriorly prolonged in front of eyes to produce a distinct snout (Fig. 3) .... Curculionidae
3′ Head anteriorly not prolonged to produce a snout 4

4(3′) Elytra long, covering entire abdomen or exposing only part of 1 terminal abdominal tergite 6
4′ Elytra abbreviated or short (Fig. 4a), exposing at least 2 entire abdominal tergites 5

5(4′) Antennae with 8 segments; minute, usually less than 2 mm long .... Hydroscaphidae, in part
5′ Antennae with 11 segments (Fig. 4b); slender, usually longer than 5 mm .... Staphylinidae

6(4) Tarsal segment III bilobed (Fig. 5) .... Chrysomelidae
6′ Tarsal segment III not bilobed 7

7(6′) The first abdominal sternite divided into a right and a left part by proximal elevated metacoxal process (Fig. 6); tarsi with 5 segments.. 8

7′ The first abdominal sternite not divide into a right and a left part; tarsi with 3-5 segments 11

8(7) Hind tibia and tarsi more or less cylindrical in cross section and lacking conspicuous swimming setae...AMPHIZOIDAE, in part

8′ Metathoracic tibia and tarsi flattened and bearing long swimming setae (Fig. 7a) .. 9

9(8′) Eyes protuberant; metasternum with a transverse suture ....HYGROBIIDAE

9′ Eyes not protuberant; metasternum without a suture 10

10(9′) Metathoracic tarsus with a single claw (Fig. 7a) ; if there are two claws, mesoscutellum large and conspicuous (Fig. 7b).......................... DYTISCIDAE, in part

10′ Metathoracic tarsus with two claws; mesoscutellum concealed (Fig. 8) .. NOTERIDAE

11(7′) Metathoracic legs with swimming setae (Fig. 7a).. 12

11′ Metathoracic legs without swimming setae.. 15

12(11) Antenna long and filiform... DYTISCIDAE, in part

12′ Antenna club-shaped (Fig. 10, 11b, 13)... 13

13(12′) Pronotum with 5 longitudinal grooves ....HELOPHORIDAE

13′ Pronotum without longitudinal grooves 14

14(13′) Pronotum narrower than elytra...HYDROCHIDAE

14′ Pronotum as wide as elytra (Fig. 9)...................................... HYDROPHILIDAE, in part

15(11′) Antennae club-shaped, with club-like segment at base of club (Fig. 10b,11b).... 16

15′ Antennae various shapes; if clubbed, tarsi and claw long (Fig. 12)...................... 17

16(15) Antennal club with 3 segments (Fig. 10b); abdomen with 5 segments visible from ventral side (Fig. 10a)... HYDROPHILIDAE, in part

16′ Antennal club with 5 segments (Fig. 11a); abdomen with 6-7 segments visible from ventral side (Fig. 11b)...HYDRAENIDAE

17(15′) Tarsi with 3 segments .... HYDROSCAPHIDAE, in part

17′ Tarsi with 5 segments 18

18(17′) Long legs with long claws; tarsal segment 5 elongate, as long as previous 4 segments combined (Fig. 12)... 19

18′ Legs and claws not elongate; length of tarsal segment 5 less than 4 segments combined .... (Fig. 14a) 20

19(18) Antennae variable, not with pectinate club .... Elmidae
19′ Antennae with pectinate club (Fig. 13) .... Dryopidae

20(18′) Hind coxae extend laterally to margin of elytra; elytra covered with short setae .... Amphizoidae, in part
20′ Hind coxae not extending to margin of elytra (Fig.14a-b) elytra covered with long slender sensory setae .... Carabidae

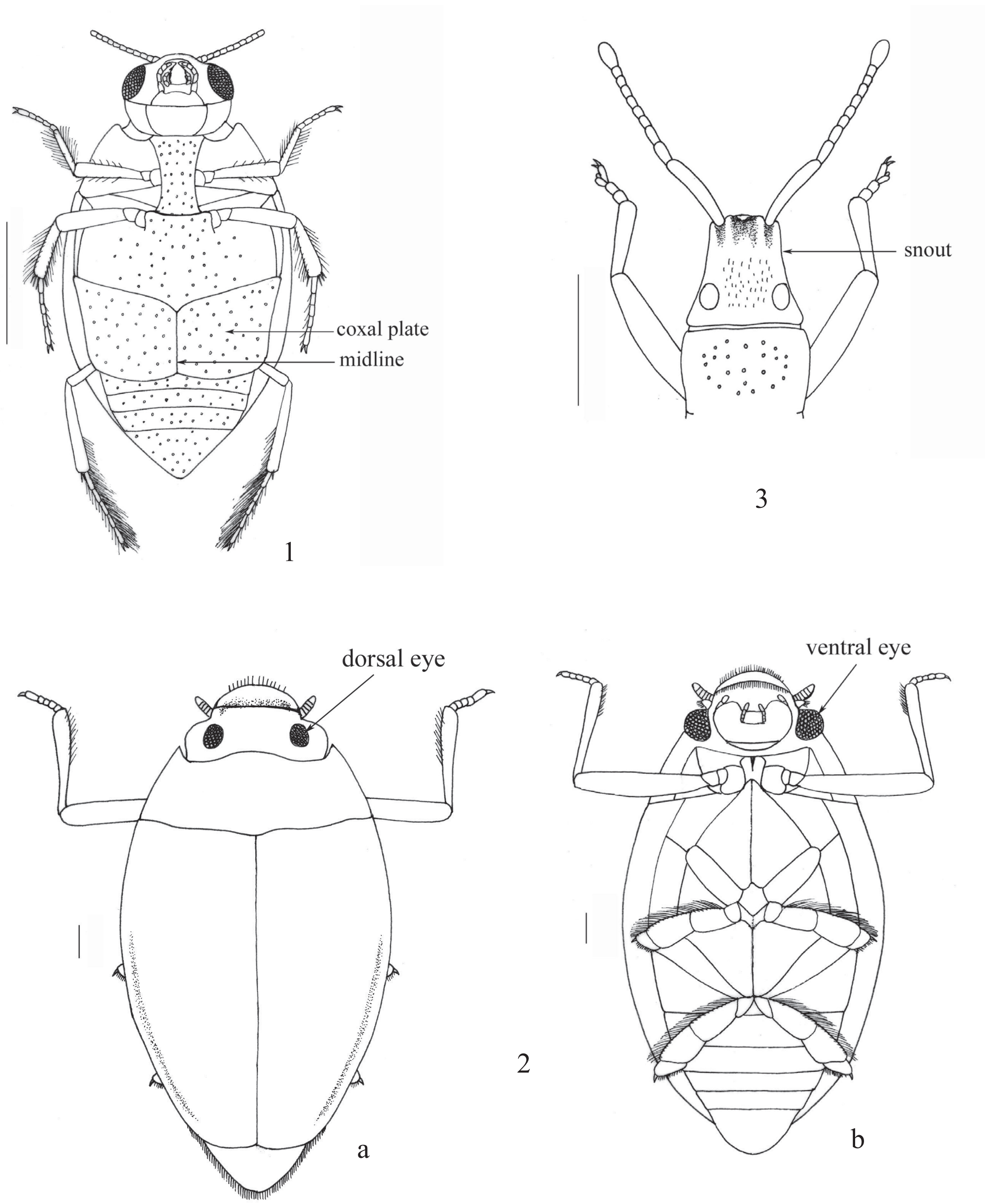
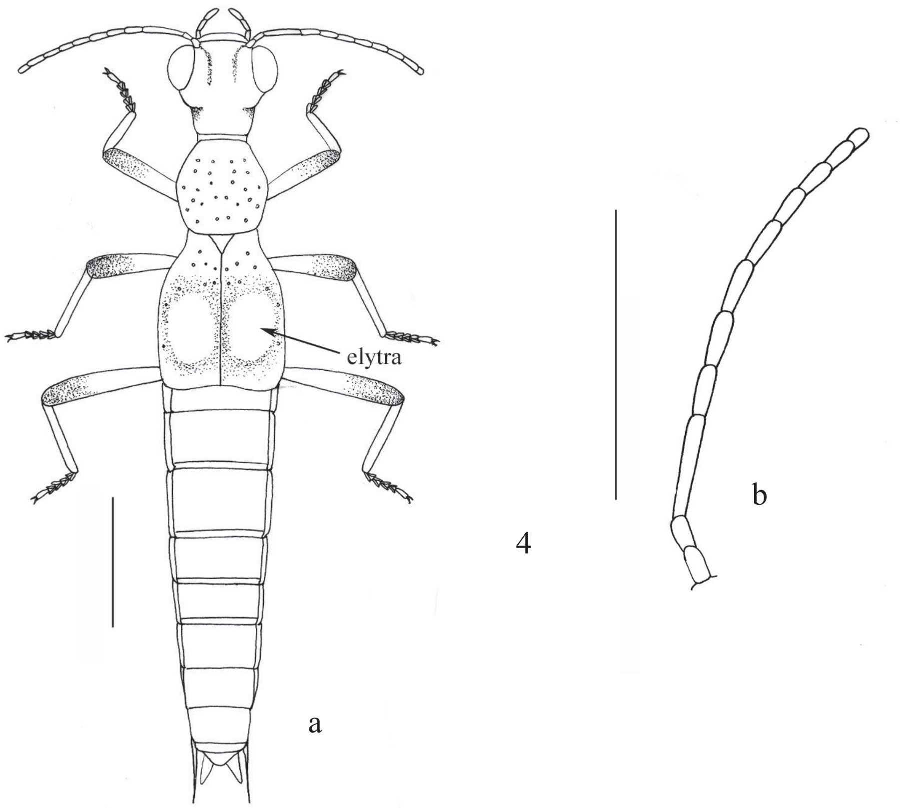
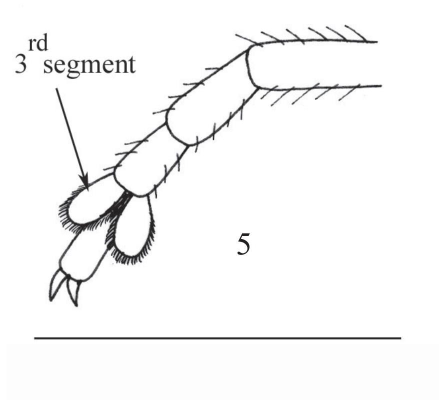


Fig. 1-3. 1. Ventral side of Halipidae; 2. Dorsal view (a) and ventral (b) of Gyrinidae; 3. Dorsal view of head of Curculionidae.
Scale = 1 mm.





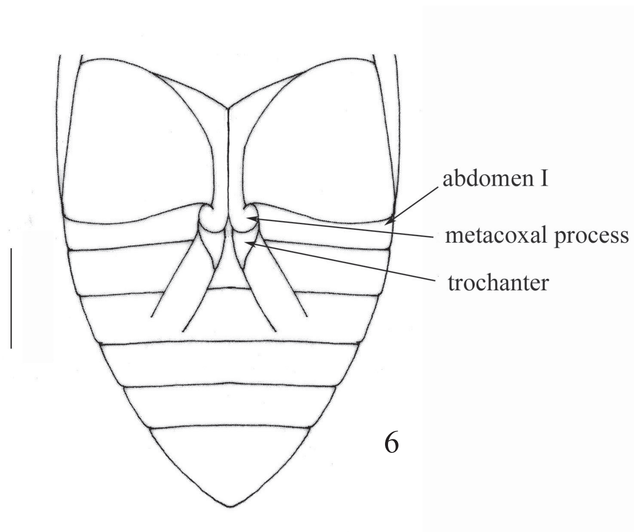


Fig. 4-6 4. Dorsal view (a) and antenna (b) of Staphylinidae; 5. Tarsal segment 3 of Chrysomelidae; 6. Ventral side of Dytiscidae.
Scale = 1 mm.

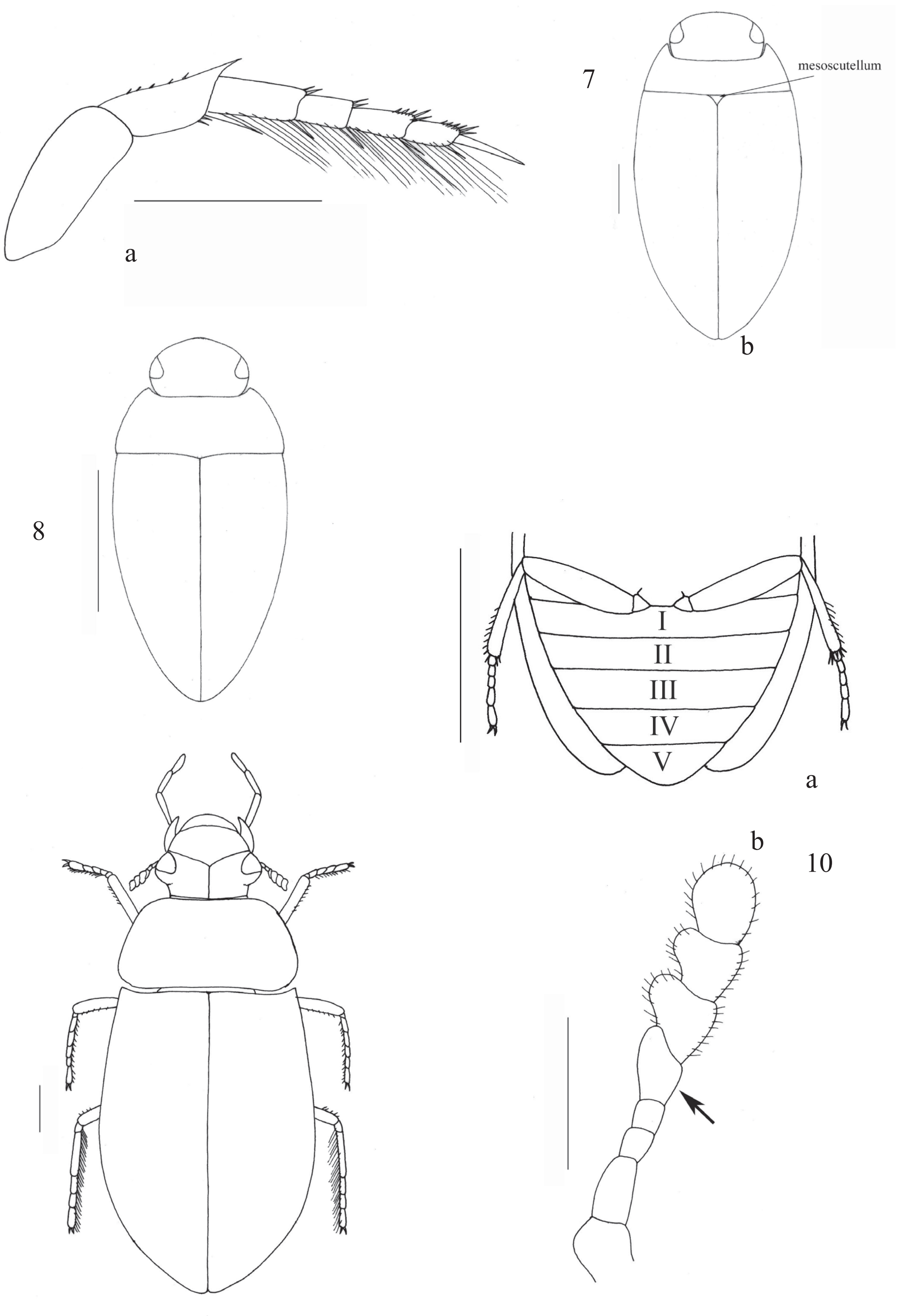


Fig. 7-10 7. Metathoracic leg (a) and dorsal view (b) of Dytiscidae; 8. Dorsal view of Noteridae; 9. Dorsal view of Hydrophilidae; 10. Ventral side of abdomen (a) and antenna (b) of Hydrophilidae.
Scale: (7b, 8, 9) 1 mm; (7a, 10a-b) 0.5 mm.

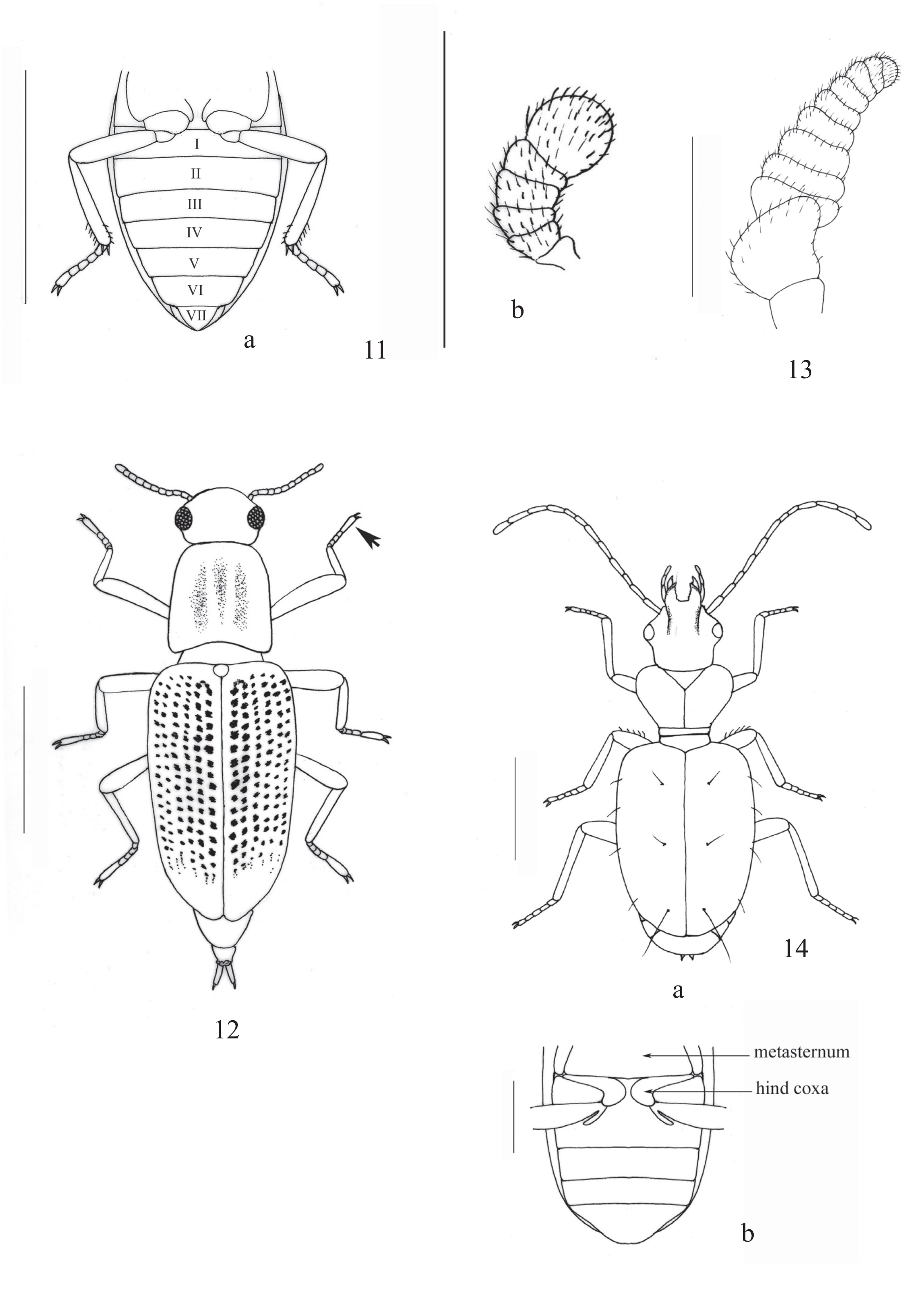


Fig. 11-14 11. Abdomen (a) and antenna (b) of Hydraenidae; 12. Dorsal view of Elmidae; 13. Antenna of Dryopidae; 14. Dorsal view (a) and abdomen (b) of Carabidae
Scale: (12, 14a-b) 1 mm (11a-b, 13) 0.5 mm.

Key to Families of Mature aquatic Coleoptera Larvae of Indochina

1 Legs absent, or present with 3-4 segments; tarsi with single claw 2
1′ Legs with 5 segments; tarsi with 2 claws (except Halipidae have a single claw) .. 14

2(1) Labrum separated from clypeus (Fig. 19b) 7
2′ Labrum not separated (Fig. 16a).. 3

3(2′) Legs present and well developed (Fig. 15, 19a) 5
3 Legs absent or reduced in size; thoracic and abdominal tergites not distinctly visible.. 4

4′ Legs well developed; thoracic and abdominal segments without hook ventrally .... Circulionidae
4′ Legs minute; last abdominal segment with a pair of hooks ventrally ....Chrysomelidae

5(3′) Body round or dorsoventrally subcylindrical; head projecting anteriorly from thorax and visible from above (Fig. 19) 6
5′ Body dorsoventrally flattened; pronotum expanded anteriorly, head not visible from above (Fig. 15).. Lampyridae

6(5) Palpiger of maxilla separated from stipe (Fig. 16b) .... Hydrophilidae
6′ Palpiger of maxilla fused with stipe (Fig. 17) .... Staphylinidae, in part

7(2′) Antennae with 2 segments ....Hydroscaphidae
7′ Antennae with at least 3 segments.. 8

8(7′) Abdomen with 10 segments, segment 9 with articulated cerci having 1-2 segments 9
8′ Abdomen with 9 segments, segments 8 and 9 sometimes with immovable urogomphi; without articulated cerci 10

9(8) Mandibles small sickle-shaped, without molar lobe .... Staphylinidae, in part
9′ Mandibles large, with molar lobe (Fig. 18) ....Hydraenidae

10(8′) Antennae distinctly longer than head capsule (Fig. 19a), with many segments .... Scirtidae
10′ Antenna short, with 2-3 segments 11

11(10′) Larva dorsoventrally very compressed; thoracic and abdominal terga expanded laterally covering head and legs (Fig. 20) ....Psephenidae

11′ Larva round or subcylindrical; head and legs visible from dorsal view (Fig. 21a).... 12

12(11′) .Posterior abdominal segment apically bifid; (Fig. 21b); head capsule with 5 ocelli ....Elmidae

12′ Posterior abdominal segment apically round; eye absent or with 6 ocelli 13

13(12′) Abdominal segment IX with operculum (as Fig. 21a); abdominal segments I-VIII without gills .... Dryopidae

13′ Abdominal segment IX without operculum; abdominal or anal gills present........... ....Ptilodactylidae

14(1′) Abdominal segment X with 2 pairs of terminal hooks (Fig. 22b), segments I-IX with lateral gills (Fig. 22a) ....Gyrinidae

14′ Abdominal segment X without terminal hooks, abdomen without lateral gills 15

15(14′) Abdomen with more than 8 segments 16

15′ Abdomen with 8 segments 17

16(15) Each leg with a single tarsal claw (Fig. 23a-b) .... Halipidae

16′ Each leg with 2 tarsal claws ....Carabidae

17(15′) Abdominal segment VIII with spiracle (Fig. 24).. 18

17′ Abdominal segment VIII without spiracle ....Hygrobiidae

18(17) Cerci as long as or longer than length of abdominal segment I (Fig. 25)................ .... Dytiscidae, in part

18′ Cerci absent or shorter than length of abdominal segment I 19

19(18′) Legs short and modified for digging; mandibles stout and never sickle-shaped...... .... Noteridae

19′ Legs long, well-developed for walking; mandibles long narrow and sickle-shaped.. .... Dytiscidae, in part

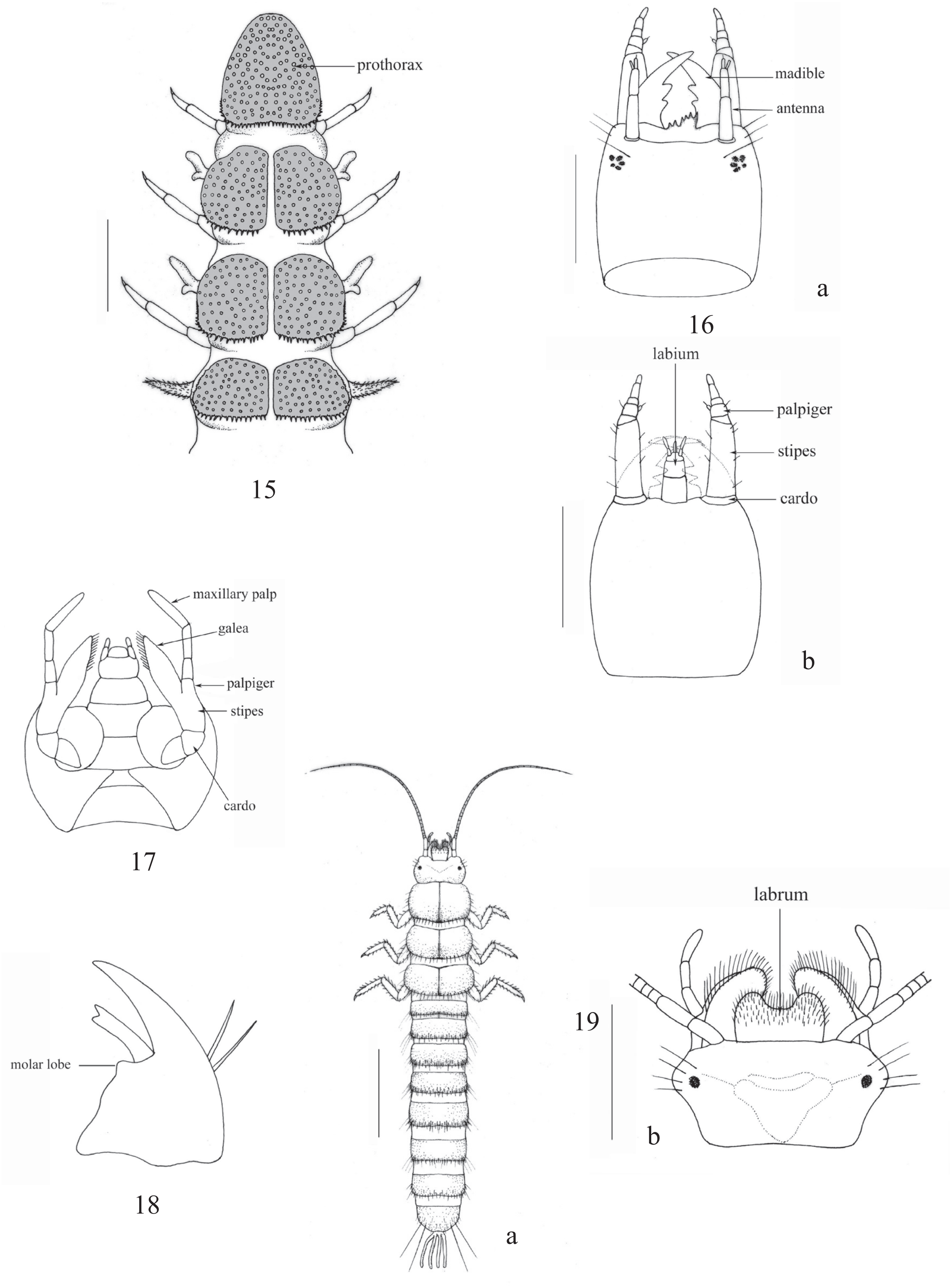


Fig. 15-19 15. Dorsal view of thoracic segments of Lampyridae; 16. Dorsal view (a) and ventral view (b) of head of Hydrophilidae; 17. Ventral view of head of Staphylinidae (redrawn from White & Brigham, 1996, fig. 20.7); 18. Mandible of Hydraenidae (redrawn from White & Brigham, 1996, fig. 20.168); 19. Dorsal view (a) and head (b) of Scirtidae.
Scale: (15, 19a) 1 mm; (16a-b, 19b) 0.5 mm.

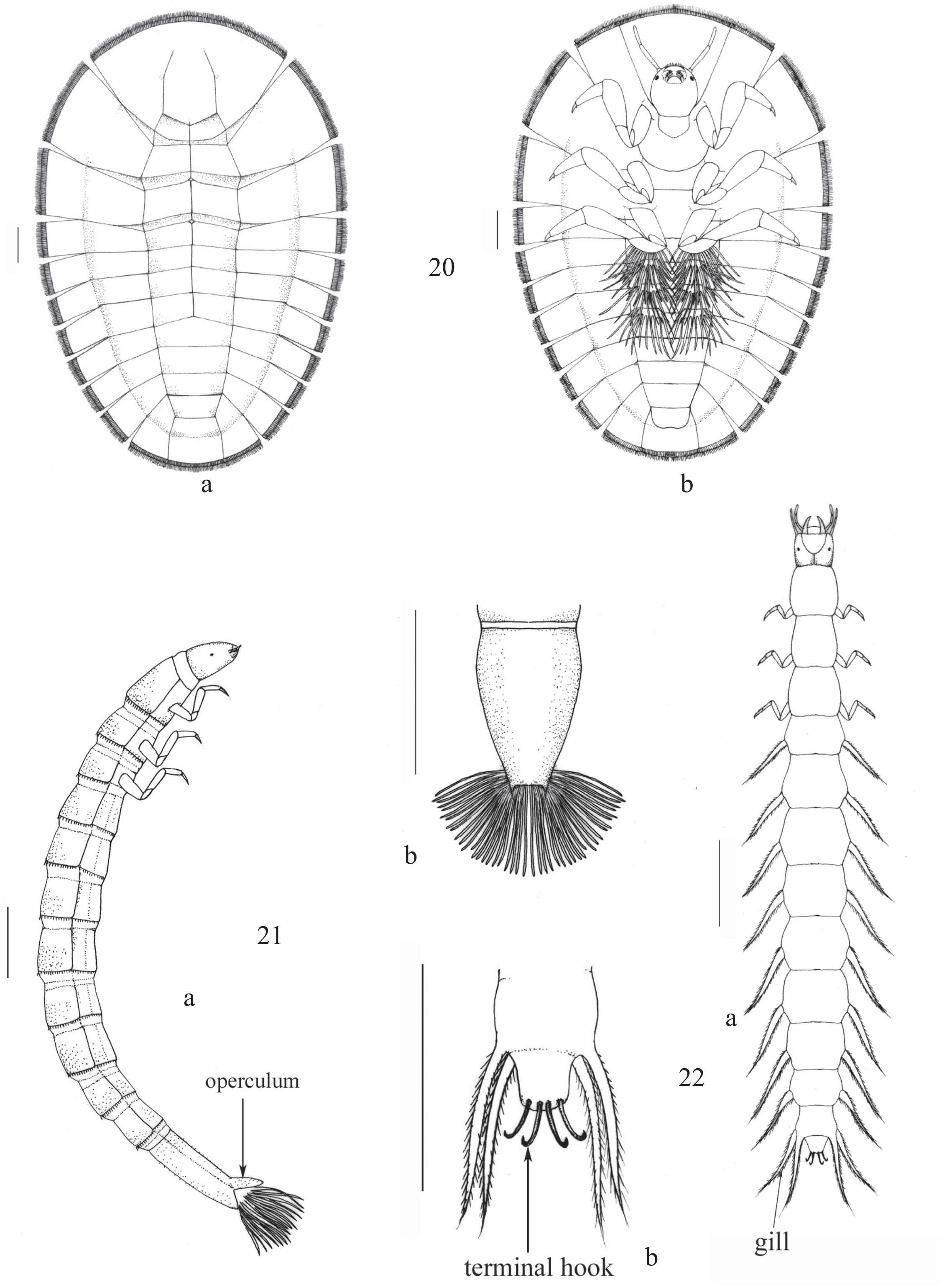
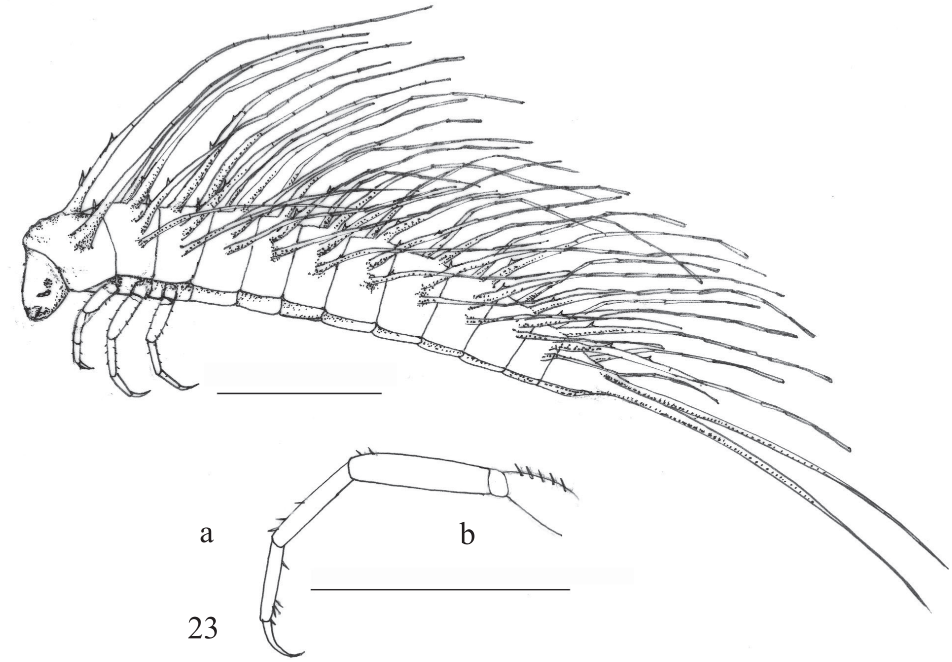
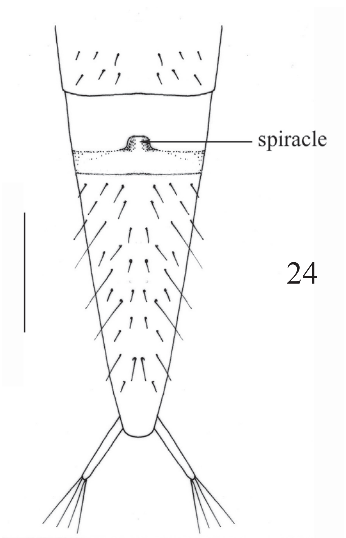


Fig. 20-22 20. Dorsal view (a) and ventral view (b) of Psephenidae; 21. Lateral view (a) and posterior end (b) of Elmidae; 22. Dorsal view of larva (a) and abdominal segment X (b) of Gyrinidae.
Scale = 1 mm.





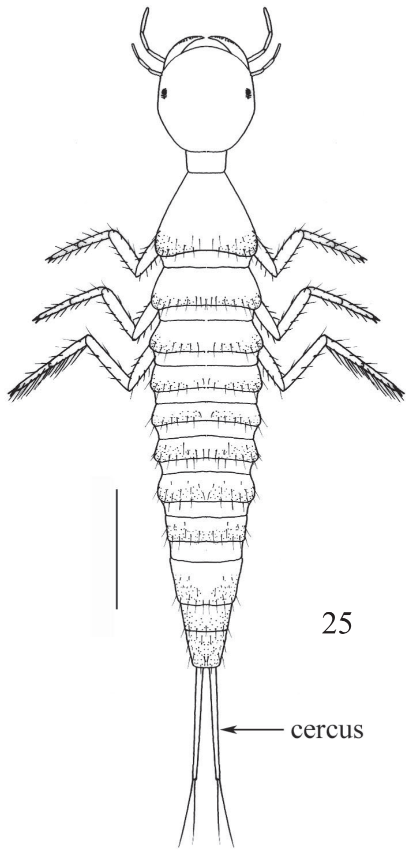
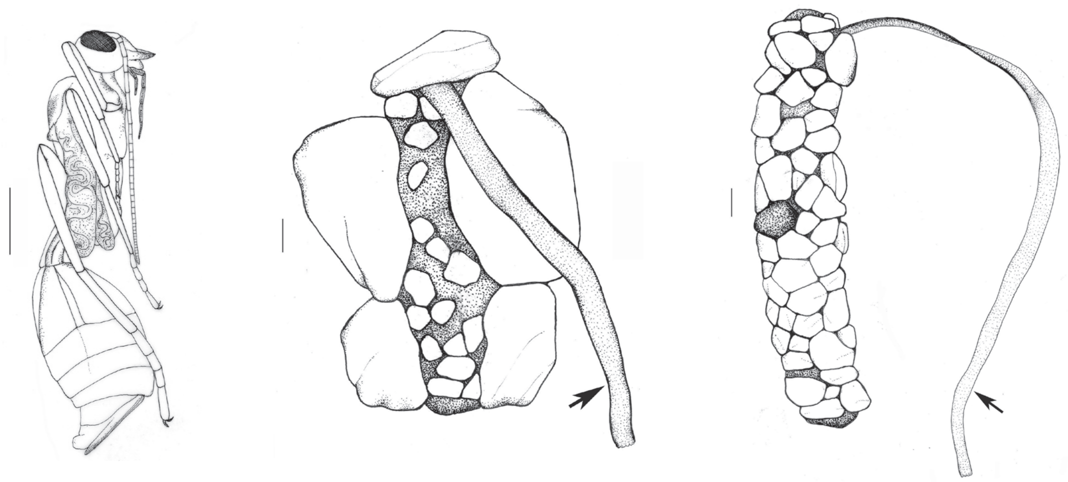


Fig. 23-25 23. Lateral view of larva (a) and foreleg (b) of Halipidae; 24. Dorsal view of abdominal segment 8 of Dytiscidae; 25. Dorsal view of larva of Dytiscidae Scale = 1 mm.

Chapter 24 Order Hymenoptera

With the exception of the spider-hunting wasp, *Anolius depressipes* Banks (Family Pompilidae, Section Aculeata), almost all members of aquatic hymenopterans are in the suborder Apocrita, Section Parasitica. They are parasitoids of aquatic insects. Adults are free living and enter the water to lay eggs on or in aquatic hosts. In most instances, Hymenoptera that parasitize aquatic insects do not show any external morphological adaptations in either the adult or larval stages, as compared with those parasitizing terrestial hosts. The larvae of internal parasites are already modified to live in a liquid environment (host hemolymph), and no special morphological modifications seem to have evolved in the wasps that dive beneath the water surface to reach their host insects. Larvae of Agriotypidae are the only external parasites of hosts that live under water. They have a special morphological adaptation: the last larval instar forms a ribbon-like respiratory filament that remains functional through the pupal stage (Fig. 1b-c). A key to families of aquatic wasps and detailed information about larvae of North America are available in Hagen (1996: cited in Merritt & Cummins, 1996).



a b c

Fig. 1 Pupa of Agriotypidae, that has been removed from the pupal case of a goerid caddisfly (a) and ribbon-like respiratory filament (b,c) produced by the parasitoid.
Scale = 1 mm.

Chapter 25 Order Diptera

Diptera, or true flies, is a large order of insects. Adults have a single pair of wings (di = two, ptera = wing) located on the mesothorax. The hind wings are reduced to a pair of club-like halteres which aid in flight. The mouth parts of adults are variously modified for piercing, licking and sucking. Larval body forms are diverse, ranging from a cylindrical body with a complete head capsule to the maggot-like body with mouth hooks only. Larvae have no jointed thoracic legs but may bear fleshy prolegs, or other structures to aid locomotion. Larvae inhabit almost all types of aquatic habitats, except open seas.

Aquatic and semiaquatic dipterans are in two suborders, Nematocera and Brachycera, with a total of 24 families (Dudgeon, 1999). Much attention and research has focused on Culicidae and Simuliidae because they are vectors of human parasites. The following key to the aquatic immature Diptera of Indochina is modified from Dudgeon (1999) and Yule (2004).

Key to Suborders, Families, Subfamilies and Genera of Mature Aquatic Diptera Larvae of Indochina

1 Larvae with a sclerotized head capsule (Fig. 7-17) (although this may be retracted into the body and may not be fully sclerotized posteriorly (Fig. 3-6); mandibles move laterally and have subapical teeth (Fig. 1) .... suborder Nematocera...2

1′ Larvae lack a head capsule entirely, or it is partially formed (Fig. 18-22); mandibles move vertically and lack subapical teeth so that they are hook-like (Fig. 2); prolegs sometimes absent and body may be pale and maggot-like....................................... .... suborder Brachycera...23

2(1) Head, thorax and abdominal segment I fused; body appears divided into seven segments; first six segments with a conspicuous ventral sucker (Fig. 3b) ....Blephariceridae...3

2′ Body not as above (with more than seven segments and lacking ventral suckers).. 5

3(2) Antennae of two poorly delimited segments connected by elongate membranous area (Fig. 3c); ventral prolegs with wide bases, tapering to point apex (Fig. 3a-b) ... . *Blepharicera*

3′ Two antennal segments well delimited, separated by short connecting membrane (Fig. 4a); ventral prolegs elongate, tapering only slightly to blunt apex.................. 4

4(3′) Antennae with two segments; shape normal, distinctly segmented; anal body division distinctly subdivided, segment 6 distinct from posterior segment; body convex, pseudopod insertions freely exposed (Fig. 4b); otherwise, shape and ornamentation variable, but never with erect strong spines .... *Apistomyia*

4′ Antennae with three segments; shape reminiscent of chiton, notches between segments and divisions barely apparent; anal body division semicircular, not subdivided, segments 6 and following fused; body depressed, flat, with strongly sclerotized lateral edge, pseudopods inserted in narrow notches; often with very long erect spines which are paired on cephalic division, but single, medial on abdominal segments ....*Horaia*

5(2′) Head very poorly developed and retractile into first thoracic segment; horizontally biting mouthparts; abdomen with 9 segments; apex of abdomen with distinctive respiratory disc containing paired spiracles, often with fleshy lobes (anal gills) (Fig. 6)..TIPULIDAE…6

5′ Head capsule fully formed and not retracted into the body cavity (Fig. 8-17); at least one proleg usually present.. 8

6(5) Body with row of dorsal and lateral elongate fleshy projections on both thoracic and abdominal segments... CYLINDROTIOMINAE

6′ Body with short, blunt projections on abdominal segments only............................ 7

7(6′) Spiracular disc bordered by five or fewer lobes variable in shape, with one dorsomedially, two laterally, and two below spiracles (Fig. 5a-b) ....LIMONIINAE

7′ Spiracular disc bordered by six subconical lobes, with two dorsally (dorsal lobes), two dorsolaterally (lateral lobes), and two below spiracles (Fig. 6a-b) ......TIPULINAE

8(5′) Prolegs present (Fig. 7-13) 9

8′ Prolegs absent (Fig. 14-17).. 18

9(8) Head directed forwards.. 10

9′ Head dorsoventrally directed; body segments bearing long fleshy tubercles and usually bearing setae (Fig. 7)................ CERATOPOGONIDAE, in part (FORCIPOMYIINAE)

10(9) Paired crochet-bearing prolegs on 1st and usually 2nd abdominal segments; posterior abdomen bearing lateral, frequently setose lobes on each side of conical anal process (Fig. 8)...DIXIDAE …11

10′ Prolegs present on thorax and/or posterior abdomen (Fig. 9-13)......................... 12

11(10) Five or more segments with crowns of setae; tips of lateral paddles almost reaching tip of the caudal appendage (Fig. 8) ....*Nothodixa*

11′ No segments with crown of setae; tips of lateral paddles clearly shorter than the caudal appendage.. *Dixa*

12(10′) Posterior of abdomen swollen; head well developed with a pair of labral fans and conspicuous mouth-brushes for filtering food from flowing water; attachs to substrate using a single sucker with radially arranged hooks on the base of their

abdomen; single thoracic proleg present; retractile gills near anus (Fig. 9- 10) ....
.... SIMULIIDAE, *Simulium*...13

12′ Not as above; pair of prolegs present on first thoracic and last abdominal segment (the front ones may be fused giving a single appearance); narrow, elongated segmented body, segment length less than twice segment width; finger-like anal gills may be present near posterior prolegs; terminal abdominal segment bears paired procerci, each with a tuft of setae which may be very long (Fig. 11-13) ....
.... CHIRONOMIDAE...16

13(12) Hypostomium very wide, with 12 or 13 apical teeth, of which median tooth is the most prominent; mandible with only one large tooth; posterior sucker composed of over 400 rows of hooks .... *Simulium (Daviesellum)*

13′ Hypostomium not so wide, with 9 apical teeth in almost horizontal row (Fig. 9b), of which lateral teeth are as prominent as, or more prominent than, median tooth; mandible with at least 2 mandibular teeth; posterior sucker composed of less than 200 rows of hooks.. 14

14(13′) Last abdominal segment with ventral papillae (Fig. 10b).................................. 15

14′ Last abdominal segment without ventral papillae .... *Simulium (Simulium)*

15(14) Lateral margin of hypostomium smooth (Fig. 10c); mandibular serrations composed of one large and one small teeth but lacking any supernumerary serration
....*Simulium (Gomphostilbia)*

15′ Lateral margin of hypostomium dentate; mandibular serrations composed of one large and one small teeth with supernumerary serration, if lateral margins of hypostomium smooth ....*Simulium (Nevermannia)*

16(12′) Antennae retractile into head; hypopharynx with distinctive toothed ligula, mentum usually weakly sclerotised (Fig. 11)...................................... TANYPODINAE

16′ Antennae non-retractile; mentum a strongly sclerotised plate (the main mouthpart), with hypopharynx lacking strong ligula 17

17(16′) Mentum associated with variably developed, but always broad and usually striated, ventromental plates (Fig. 12a-b)... CHIRONOMINAE

17′ Mentum without, or at most with relatively small, non-striate ventromentral plates (Fig. 13a-b) ....ORTHOCLADIINAE

18(8′) Thoracic and abdominal segments similar; body slender, with bead-like segments often more than twice as long as wide; variable body shape but typically long, white and worm-like with no prolegs or gills (Fig. 14)................. CERATOPOGONIDAE

18′ Thoracic segments differentiated from abdominal segments; abdominal segment length often less than segment width.. 19

19(18′) Three thoracic segments fused and enlarged, broader than abdominal segments; thoracic and abdominal segments with prominent lateral fanlike tufts of long setae and/or terminal segment with an anal setal fan 20

19′ Elongate, usually darkly-sclerotized and setose, with conspicuous sclerotized head capsule that is not retracted; mouthpart sunk in preoral cavity; trunk with 10 clearly demarcated segments and terminal region of two or more fused abdominal segments; many body segments bearing dorsal sclerotized plates ....PSYCHODIDAE

20(19) Antennae prehensile (grasping), with long apical setae; mouth brushes absent; two prominent air sacs in each of abdominal segment VII and the thorax (Fig. 15)......... ....CHAOBORIDAE

20′ Antennae not prehensile and with only short apical setae; prominent mouth brushes present on either side of labrum (Fig. 16-17) .... CULICIDAE…21

21(20′) Abdominal seta I usually with well developed leaflets (palmate) on most abdominal segments; siphon absent (Fig. 16a-b) ....ANOPHELINAE, *Anopheles*

21′ Abdominal seta I never with well developed leaflets (palmate); siphon present (Fig. 7) 22

22(21′) Very large; purplish or reddish in life; mouth brushes with about 10 flattened, non-pectinate blades; comb scales and pectin teeth absent from siphon .... TOXORHYNCHITINAE, *Toxorhynchites*

22′ Not unusually large; reddish in life; mouth brushes with numerous fine, simple filaments, if thick, the filament not simple; comb scales always present and pectin teeth on siphon present or absent (Fig. 17)... CULICINAE

23(1′) Head capsule partially developed (Fig. 18-20), with some sclerotization visible and protruding from thorax, palps and antennae visible; mandibles usually sickle shaped; without cephalopharyngeal skeleton (Fig. 2) 24

23′ Head capsule not developed, with no external visible sclerotization and antennae absent; mandibles replaced by hooks attached to a characteristic cephalopharyngeal skeleton 28

24(23) Posterior spiracles close together and concealed within terminal fissure of last segment (Fig. 18,19)... 25

24′ Posterior spiracles quite widely separated, not concealed on last segment (Fig. 21,22) 26

25(24) Terminal fissure of last segment vertical; body soft, cylindrical in form, usually white, green or some shade of brown in color, often patterned with darker band; head capsule completely retractable and includes a pair of curved mandibles; respiratory siphon is present at the tip of the anal segment (Fig. 18)........ TABANIDAE

25′ Terminal fissure of last segment horizontal; head capsule complete, strongly sclerotized and non-retractile; body flat with strongly sclerotized head capsule; 3 thoracic and 8 abdominal body segments; cuticle has a rough, honeycomb or mosaic appearance originating from calcium carbonate excretions; tapering posterior end bearing an apical coronet of plumose hydrofuge setae (Fig. 19)... STRATIOMYIDAE, *Odontomyia*

26(24′) Abdominal segments I-VII each bear a ventral pair of prolegs, and slender dorsal and ventral finger-like projections (Fig. 20), or apex of abdomen with one proleg and two long, setose 'tails' (Fig. 21).. ATHERICIDAE…27

26′ Larva not flattened, without lateral tubercles on abdominal segments; anal segment with a single median projection below the posterior spiracles; if aquatic larvae their anal segment with several finger-like lobes and body with pseudopods or welts (Fig. 22) .... EMPIDIDAE

27(26) Elongate projections on abdominal segments VI-VIII distinctively longer than these segments combined; segments I-V with no elongate projections; segment VIII with no pseudopod (Fig. 20)..*Atrichops*

27′ Elongate projections on abdominal segments VI-VIII distinctly shorter than those segments combined; segments II-V with elongate projections; segment VIII with pseudopods; either side of abdominal segment VIII and that of terminal projection without horizontal row of setae (Fig. 21) ....*Suragina*

28(23′) Larvae with an extendable, posterior respiratory tube which is well over half the length of the body; anterior end of the body rather blunt..........................SYRPHIDAE

28′. Body ends in a short respiratory tube that is divided at the apex ....EPHYDRIDAE

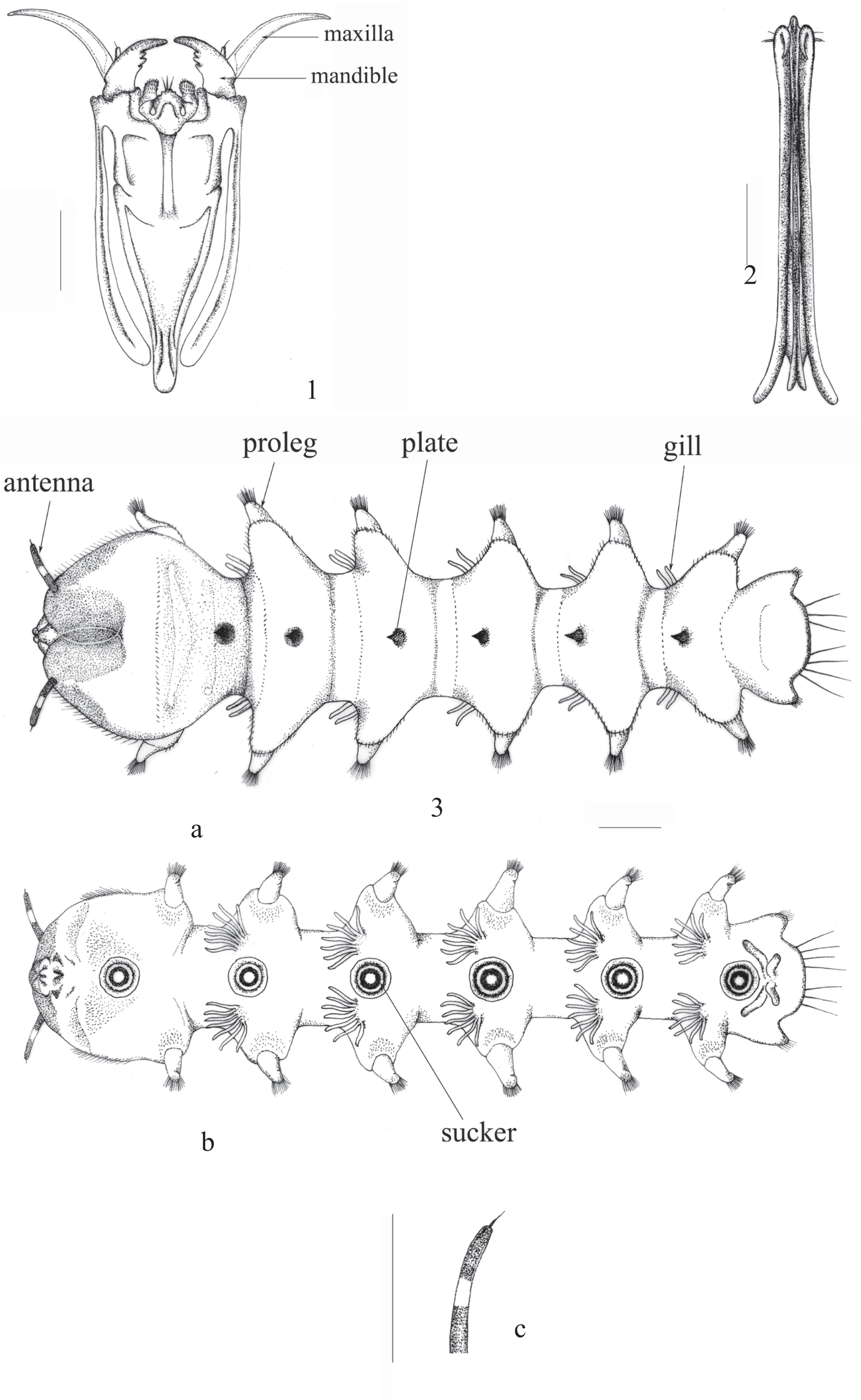


Fig. 1-3 1. Ventral view of head capsule of *Hexatoma* sp. (Tipulidae); 2. Ventral view of head capsule of *Suragina* sp. (Athericidae); 3. Dorsal view (a), ventral view (b) and right antenna (c) of *Blephariceera* sp. (Blephariceridae).
Scale: (2,3a,3b) 1 mm; (1,3c) 0.5 mm.

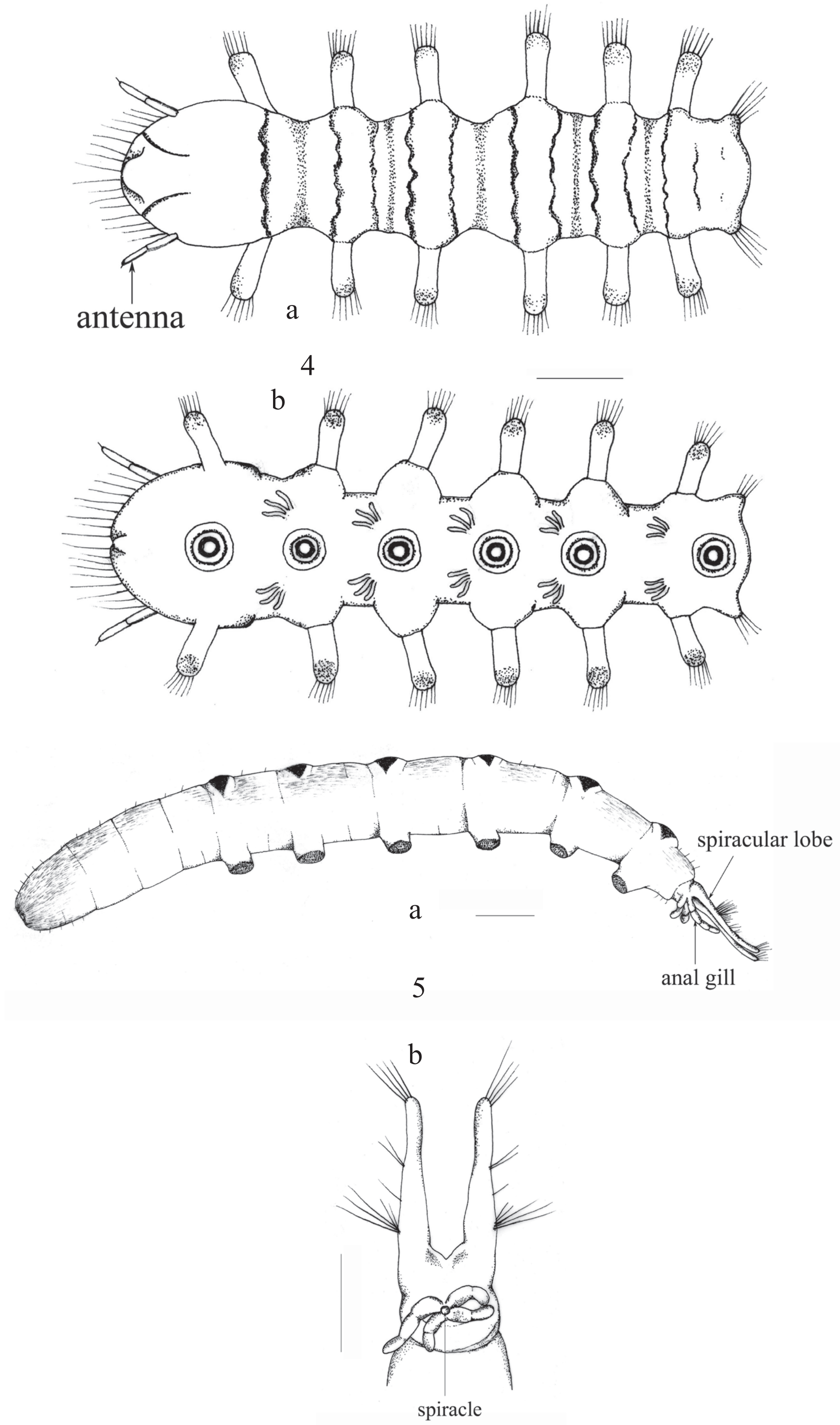


Fig. 4-5 4. Dorsal view (a) and ventral view (b) of *Apistomyia* sp. larva (Blephariceridae); 5. Lateral view (a) and caudal filaments (b) of *Antocha* sp. larva (Limoninae, Tipulidae).
Scale = 0.5 mm.

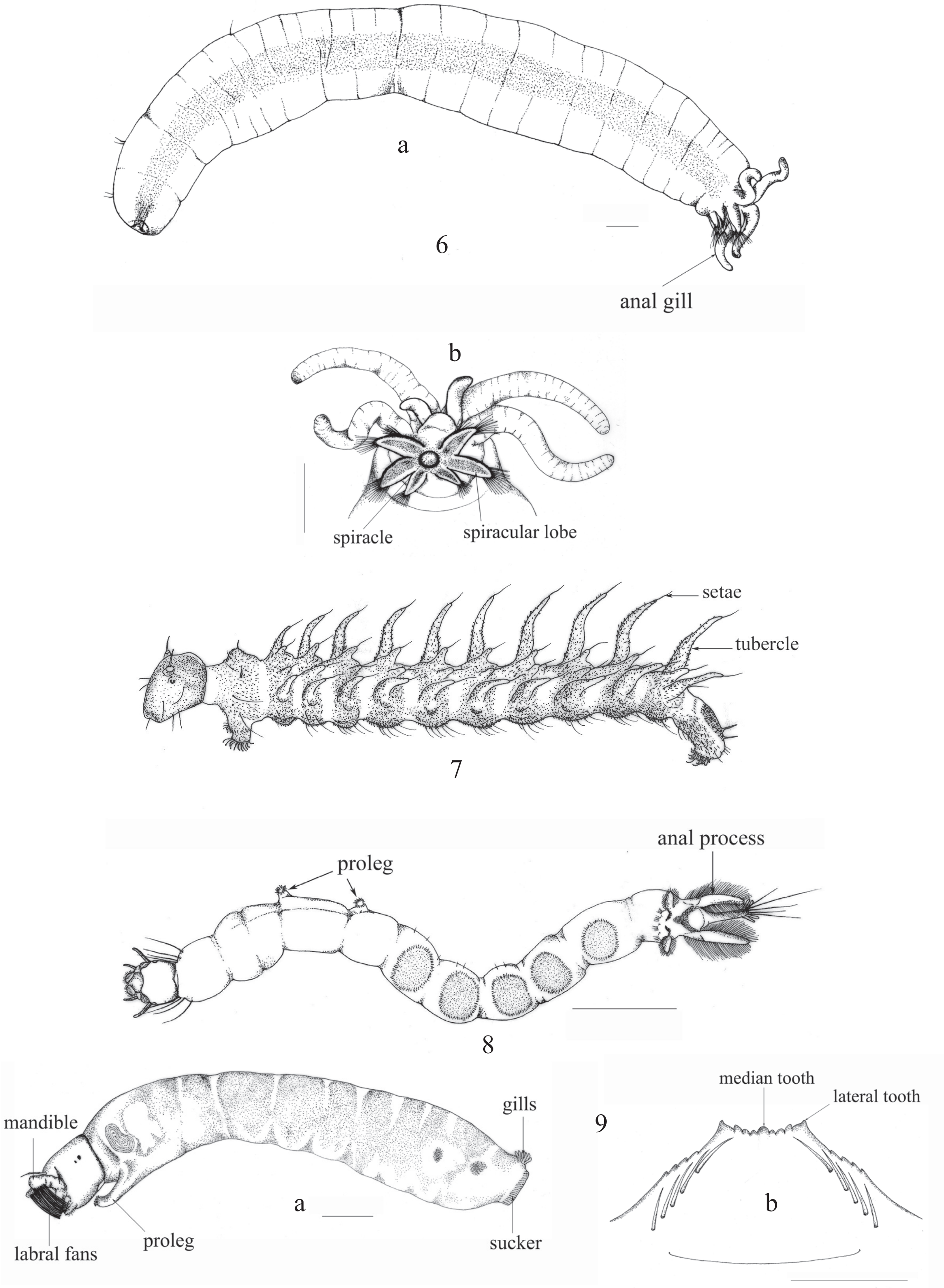
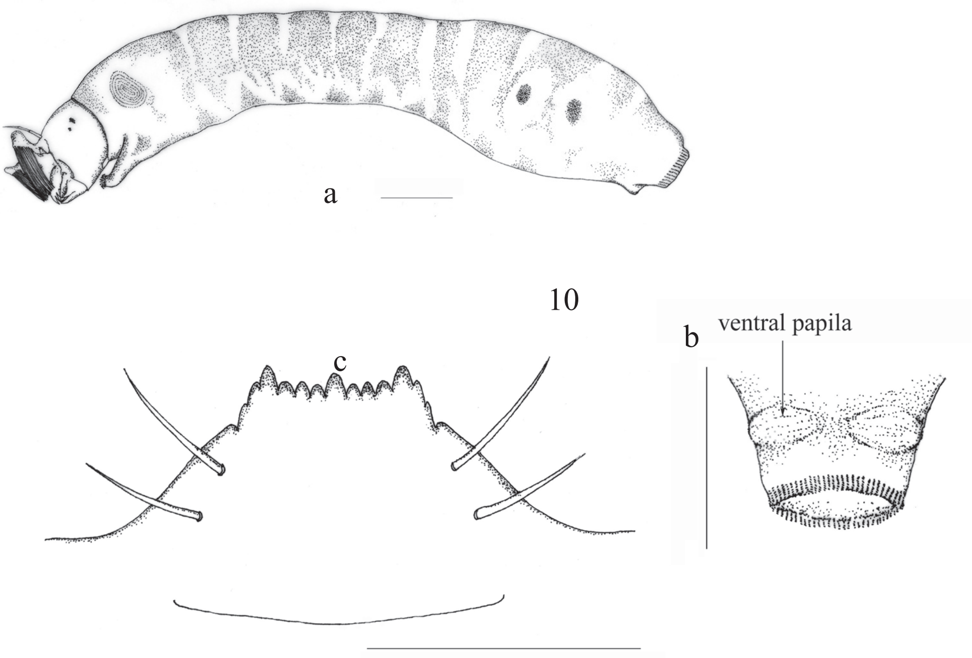


Fig. 6-9 6. Lateral view (a) and terminal abdominal segment (b) of *Tipula (Arctotipula)* sp. (Tipulinae, Tipulidae); 7. Lateral view of *Atrichopogon* sp. (Forcipomyiinae, Ceratopogonidae) (redrawn from Courtney, 1994, fig. 18.23); 8. Dorsal view of *Nothodixa* sp. (Dixidae); 9. Lateral view (a) and hypostoma (b) of *Simulium (Simulium) fenestratum* (Simuliidae).
Scale: (6a-b, 7, 8, 9a) 1 mm; (9b) 0.1 mm.



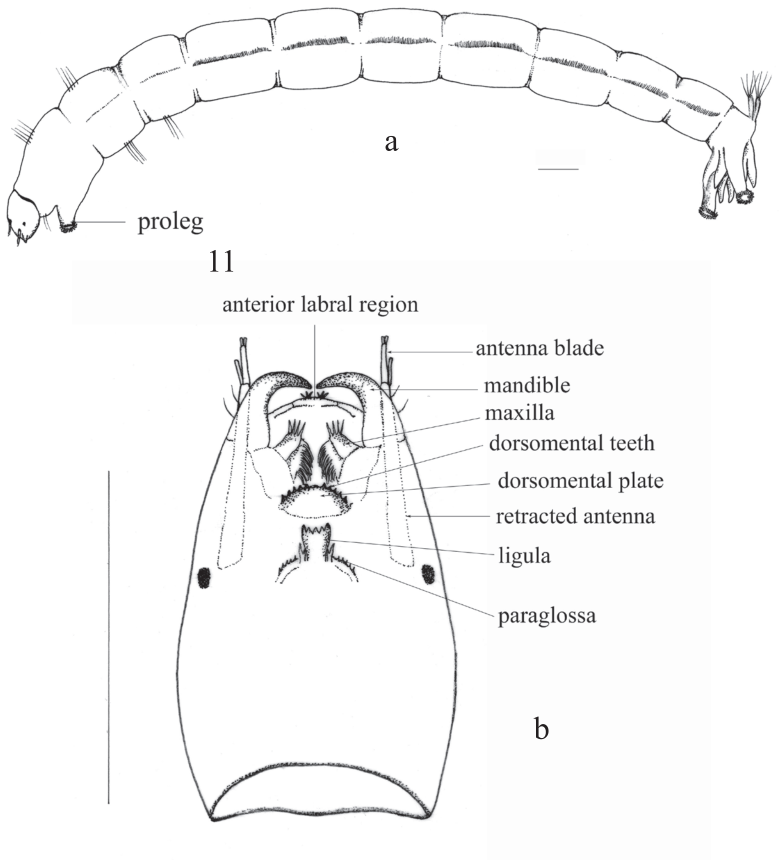


Fig. 10-11 10. Lateral view (a), ventral papillae (b), and hypostoma (c) of *S. inthanonense* (Simuliidae); 11. Lateral view (a) and ventral view of head capsule (b) of *Thiennemannimyia* sp. (Tanypodinae, Chironomidae).
Scale: (10a-b, 11a) 1 mm; (10c, 11b) 0.5 mm.

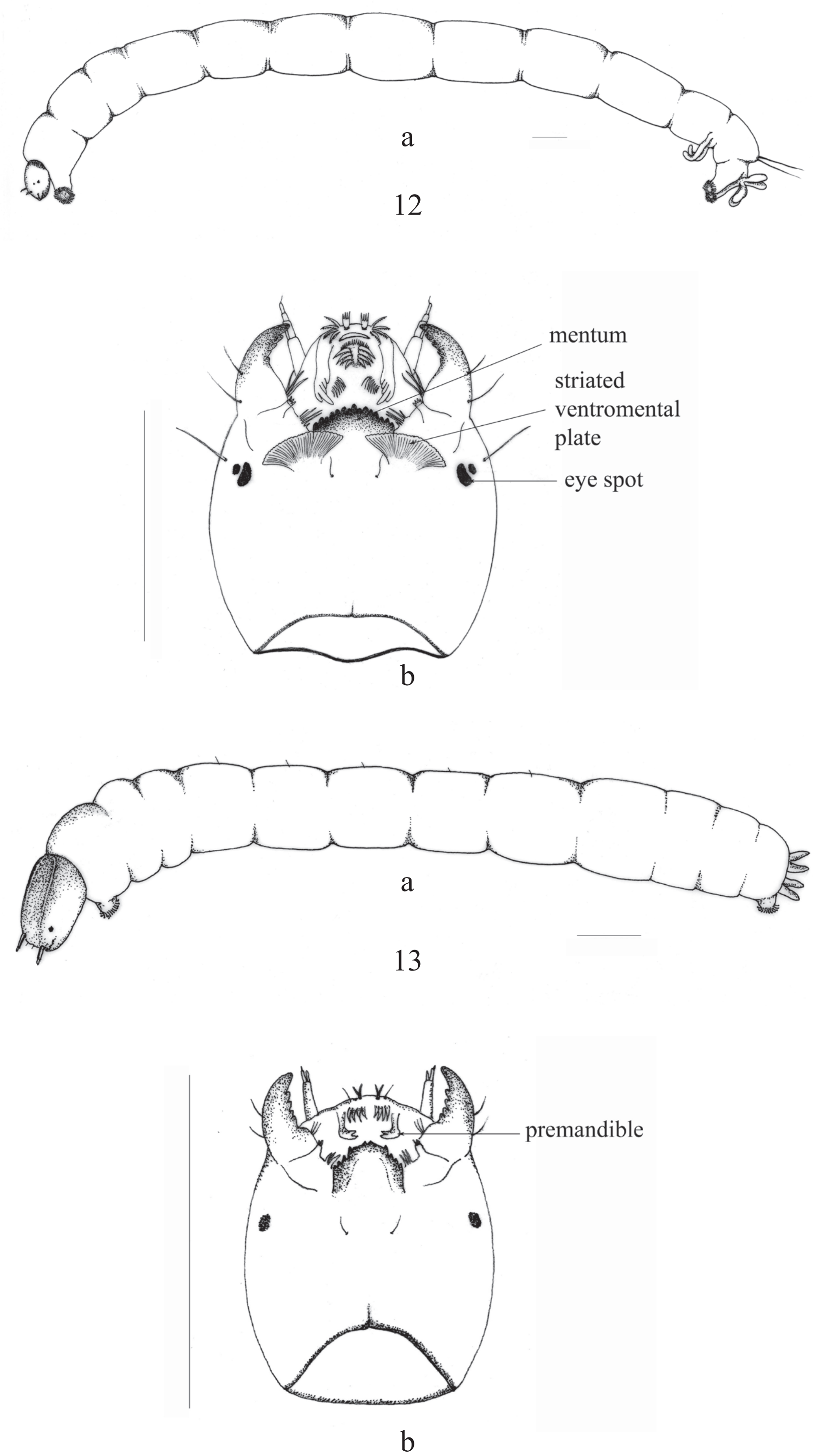


Fig. 12-13 12. Lateral view (a) and ventral view of head capsule (b) of *Kiefferulus* sp. (Chironominae, Chironomidae); 13. Lateral view (a) and ventral view of head capsule (b) of *Nanocladius* sp. (Orthocladiinae, Chironomidae).
Scale: (12a, 13a) 1 mm; (12b, 13b) 0.5 mm.

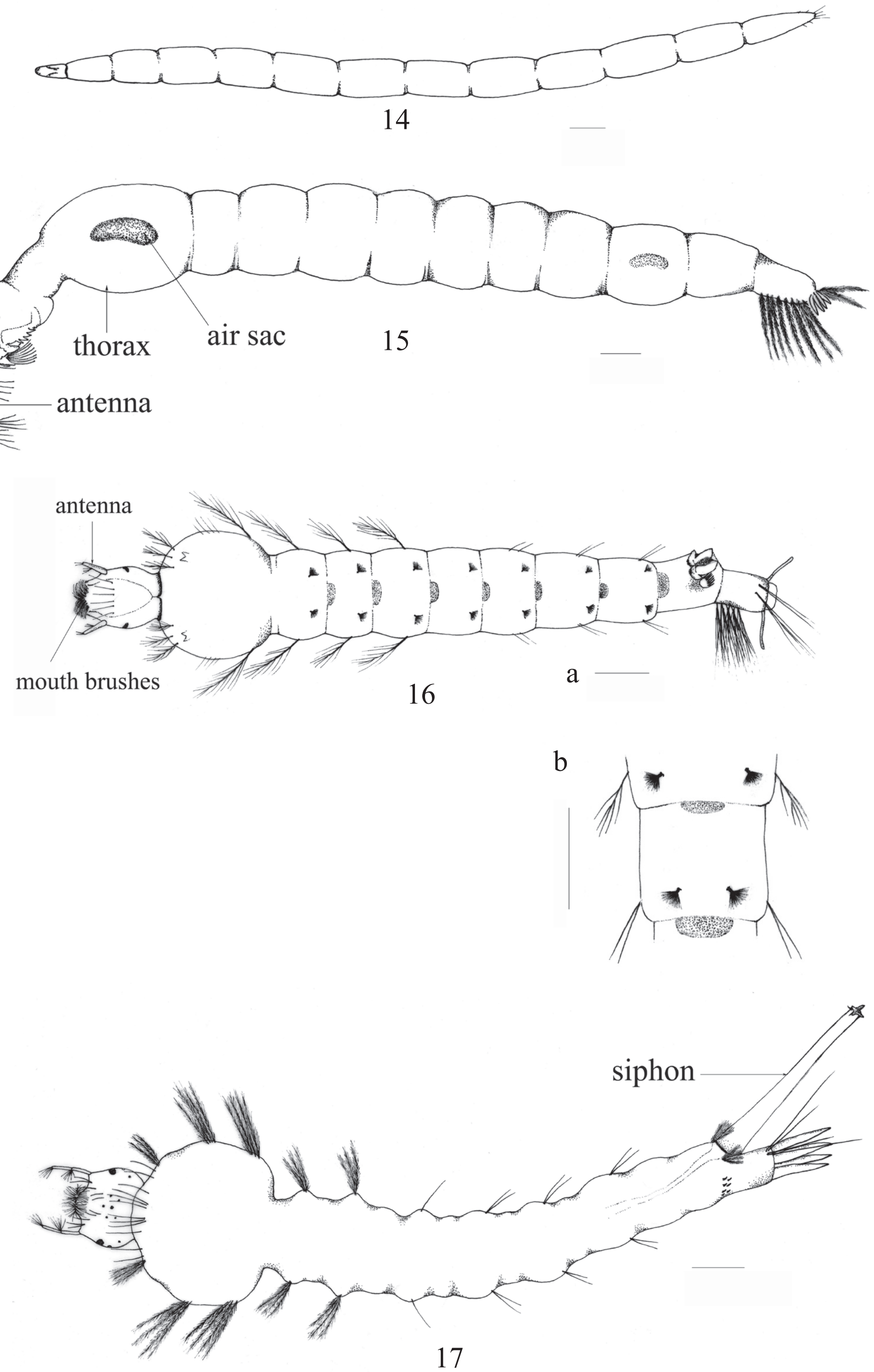
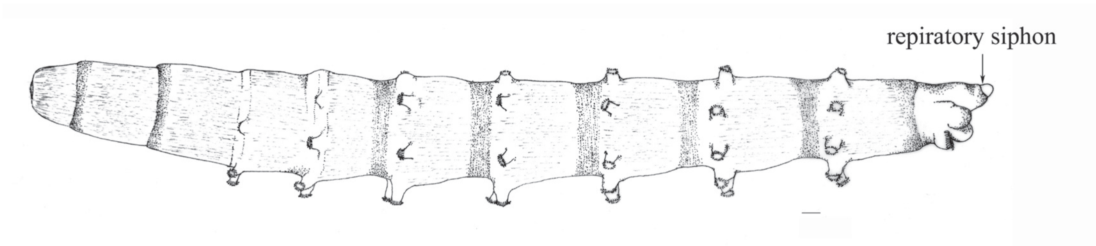


Fig. 14-17 14. Dorsal view of *Bezzia* sp. (Ceratopogonidae); 15. Lateral view of *Chaoborus* sp. (Chaoboridae); 16. Dorsal view (a) and ventral view of abdomen (b) of *Anopheles* sp. (Anophelinae, Culicidae); 17. Dorsal view of culicid (Culicinae, Culicidae).
Scale = 1 mm.



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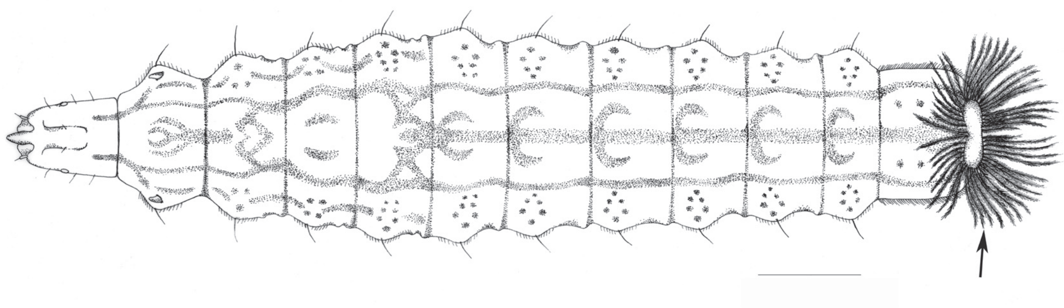

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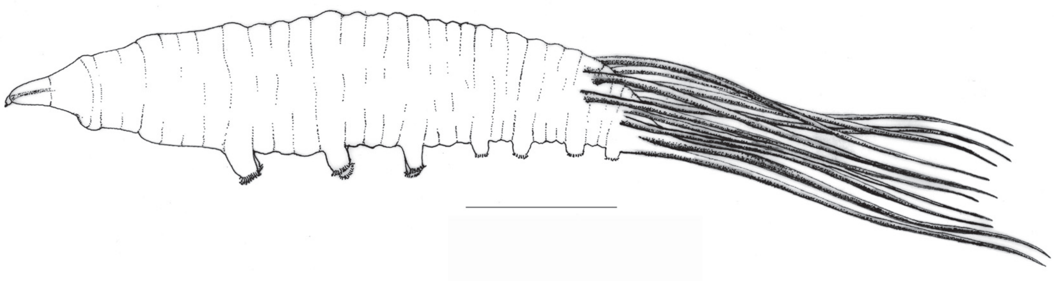

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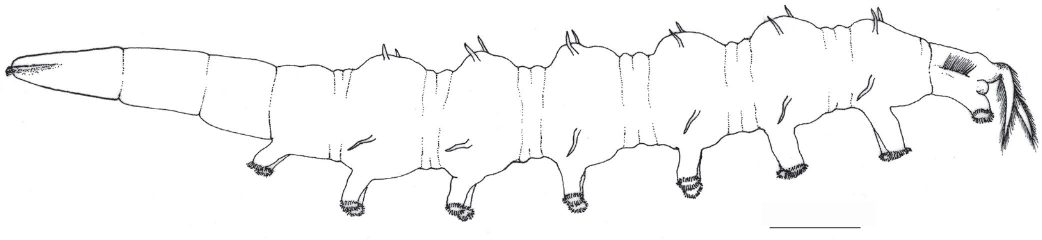
Fig. 18-20 18. Lateral view of Tabanidae; 19. Dorsal view of *Odontomyia* sp. (Stratiomyidae); 20. Lateral view of *Atrichops* sp. (Athericidae). Scale = 1 mm.



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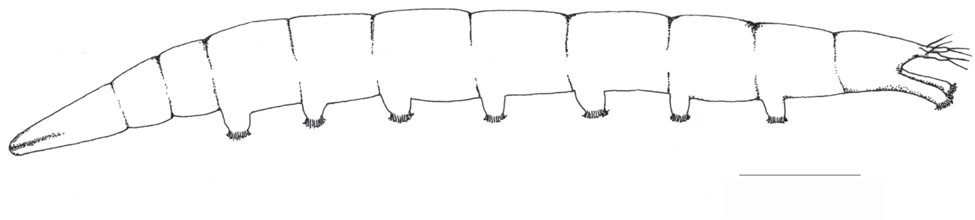

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Fig. 21-22 21. Lateral view of *Suragina* sp. (Athericidae); 22. Lateral view of *Hemerodromia* sp. (Empididae).
Scale = 1 mm.

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Glossary

A

Aboral	The part of the body opposite the mouth.
Acoelomate	Without a body cavity between the outer body wall musculature and gut.
Adductor	A muscle that draws the two valves of a mollusc shell together.
Alloistrophic	Protochonch and telechonch are in the different direction.
Ametabola	Without metamorphosis.
Amictic	The diploid eggs produced by female rotifers that can not be fertilized.
Anteapical	Just proximal of the apex.
Anteclypeus	An anterior division of the clypeus.
Antenna	A sensory appendage on the head of arthropods.
Antennal gland	Excretory organ of crustaceans located in the antennal metamere.
Aperture	An opening into the first whorl of a snail shell.
Apopyle	Opening of the radial canal into the spongocoel of the sponges
Apterous	Wingless.
Asconoid	Simple canal system of sponges, with canal leading directly from the water outside to the internal spongocoel.
Auricle	The ear-like lobe in planarians.

B

Benthic	Living on the substrates at the bottom of aquatic habitats.
Biramous	Two branched.
Bipectinate	Having branches on two sides like teeth of a comb.
Brachypterous	With short wings that do not cover the abdomen.
Buccula	One of two ridges on the underside of the head, on each side of the beak.

C

Campodeiform	An active larva with a shape that is elongate and flattened and has well-developed legs and antennae.

Carapace	Shield-like plate covering the cephalothorax of some crustacean such as shrimps and crabs.
Cardiiform	Heart-shaped.
Cardinal (tooth)	One of two basic categories of teeth in bivalves, cardinal teeth and lateral teeth.
Carina	A keel or ridge.
Carpus	Fourth of basically six segments of inner branch (endopod) of a thoracopod.
Caudal	Belonging to or relating to the tail.
Cephalothorax	A body division found in some arthropods in which head is fused with some or all of the thoracic segments.
Cercus (Cerci)	One of a pair of appendages at the posterior end of the abdomen.
Cervical gill	Gill on the neck.
Chelicerae	A pair of anterior appendages in spiders and mites.
Chitin	A horny substance made of nitrogenous oligosaccharides that forms part of the cuticle of arthropods.
Choanocyte	One of the flagellated collar cells that line cavities and canals of sponges.
Claval suture	The suture of the front wing separating the clavus from the corium.
Clitellum	A thickened portion of certain segments of oligochaetes and leeches.
Cnidoblast	Modified interstitial cell that holds the nematocyst in cnidarians.
Cocoon	The protective covering for the developing embryos of some annelids, or the protective covering and its pupa in endopterygote insects.
Coelom	An internal body cavity lying between the outer body wall musculature and gut.
Collophore	A tube-like structure located on the ventral side of the first abdominal segment of collembolans.
Collumella (axis)	Calcareous structure forming central axis of snail shells.
Commissure	A structure that connects the left and right sides of a segment.
Connexival	A line of contact between dorsal and ventral laterotergites on the lateral margin of the abdomen.
Corium	The elongate, thick, basal portion of the front wing.
Corneous	Of a horny or chitinous substance; resembling horn in texture.
Corona	Ciliated disc on anterior end of a rotifer.

Coxa	The proximal joint of an arthropod leg or protopod.
Cruciform	The relatively small muscle spanning posteroventrally between valves; intersect in midbody to from cross.
Cuticle	The noncellular organic protective layer of the body wall secreted by the hypodermis of many invertebrates.
Clypeus	A scerite on the lower part of the face, between the frons and the labium.

D

Dactylus	Seventh segment of thoracopod; may serve as movable element in terminal pincer (chela).
Demarcation	The action of fixing boundaries or limits, a dividing line.
Desclerotize	Loss of sclerotin in normally sclerotized parts or structure.
Detritus	Particles of dead organic matter suspended in water or lying on the bottom.
Devoid	Entirely lacking in.
Dextral	On the right; in gastropods, shell is dextral if opening is to right of columella when held with spire up and facing observer.
Dioecious	Having separate sexes.
Diploblastic	Possessing two distinct tissue layers during embryonic development (ectoderm and endoderm).
Discoid	Shape like a disc.
Distal	Near or toward the free end of an appendage.
Divergence	Become more separated distally.

E

Ectoderm	An outer germ layer of cells of an embryo.
Endoderm	An innermost germ layer of embryo.
Endopterygote	Having the wings developing internally; with complete metamorphosis.
Elytra	A thickened, leathery, or horny front wing.
Endopodite	Medial branch of a biramous appendage of crustacean.
Epistome	Flap over the mouth in some bryozoans.
Exoskeleton	A supporting structure secreted by the epidermis of arthropods.
Exopodite	Lateral branch of a biramous appendage in crustacean.
Exopterygote	With the wing developing on the outside of the body, as in insects

with simple metamorphosis.

F

Femur	The third leg segment, located between the trochanter and the tibia.
Filter feeding	Any feeding process by which particulate food is filtered from water in which it is suspended.
Fouling	i) Contamination of feeding or respiratory area of snail by its waste products.
	ii) Accumulation of sessile organisms on the hull of a ship or boat.
Fovea	A small pit or depression.
Furcula	The forked spring apparatus of the Collembola.

G

Gastrodermis	Lining of the digestive cavity of cnidarians.
Gastrovascular cavity	Body cavity of the Cnidarians that functions in both digestion and circulation and has a single opening serving as both mouth and anus.
Gemmule	Resistant cyst-like asexual reproduction unit of freshwater sponges.
Globose	Spherical or nearly spherical.
Glossa	One of a pair of lobes at the apex of the labium between the paraglossae.
Glochidium	Bivalve larval stage of freshwater pelecypod.

H

Haltere	A small knobbed structure on each side of the metathorax, formed from a modified hind wing (in Diptera).
Hemimetabolous	Having simple metamorphosis, like that in the Odonata, Ephemeroptera and Plecoptera.
Hemelytra	The front wing of Hemiptera.
Hinge teeth	The teeth along dorsal margin which function during opening and closing of shell.
Hirsute	Having abundant setae on the body, setose.
Homeostrophic	Protoconch and teleconch are in the same direction.
Hypognathous	With the head and the mouthparts directed ventrally.
Hypostomium	A mound-like structure located around the mouth in hydras.

I

Imago	The adult or reproductive stage of an insect.
Infracoxal	Below the coxa.
Ischium	Second of basically six segments of inner branch (endopod) of thoracopod.

L

Labium	The lower lip of insect.
Labrum	The upper lip of insect.
Lamelliform	Plate-like shape.
Laminate	Plate-like structure.
Lanceolate	Spear-shaped, tapering at each end.
Larva	An immature stage in the life history of many invertebrates in which morphology differs from adults.
Ligula	The terminal lobe of the labium, the glossae and paraglossae.
Lorica	A secreted, protective covering in rotifers.
Lophophore	Tentacle-bearing ridge which is an extension of the coelomic cavity in Bryozoa (Ectoprocta).

M

Macropterous	Fully winged.
Malpighian tubules	Excretory organs of insects and some arthropods; they are blind tubes opening into the hindgut.
Mantle	Soft extension of the body wall in molluscs which secretes a shell.
Mastax	Pharyngeal mill of rotifers.
Membranous	Like a membrane.
Mentum	The distal part of the labium, which bears the palps and the ligula.
Mesoepimeron	The epimeron of the mesothorax.
Mesoglea	Jellylike material between the epidermis and gastrodermis of cnidarians.
Mesohyl	The jellylike matrix surrounding cells of sponges.
Mesosternum	The sternum, or ventral sclerite, of the mesothorax.
Metamorphosis	A change in form during development.
Molt	A process of shedding the exoskeleton; ecdysis; to shed the exoskeleton.

Monecious	Having both male and female in one individual.

N

Nacreous	Innermost layer of mollusc shell, secreted by mantle epithelium.
Nematocyst	Stinging organelle of cnidarians.
Nodate	A strong crossvein near the middle of the costal border of the wing.
Nymph	An immature stage of an insect that does not have a pupal stage.
Nauplius	A free-swimming larval stage of certain crustaceans, with three pairs of appendages: antennules, antennae and mandible; and a median (nauplius) eye.

O

Occipital ridge	A ridge extending between the compound eyes on the caudodorsal angle of the head.
Occiput	The dorsal posterior part of the head between the occipital and postoccipital sutures.
Ocellus	A simple eye or eye spot in many invertebrates.
Operculum	A lid or plate closing the opening into a snail shell.
Osculum	Excurrent opening of sponges.
Ostium	Any opening through which water enters a sponge.
Ostiole	A small opening.
Oviparous	Reproduction in which eggs are released by female; development of offspring occurs outside the maternal body.
Ovoviviparous	Reproduction in which eggs develop within the maternal body and hatch within the mother, or immediately after laying.

P

Palp	A segmented process born by the maxillae or labium.
Palpiger	The lobe of the mentum of the labium that bears the palp.
Papilla	A small nipplelike elevation.
Paraglossa	One of a pair of lobes at the apex of the labium, lateral to the glossae.
Paramere	A lobe or process at the base of the aedeagus (in male genitalia).
Parasitoid	An animal that feeds in or on another living animal of a relatively long time, consuming all or most of its tissues and eventually killing it.

Parthenogenesis	Development of an unfertilized egg into a functional adult.
Penultimate	Next to the last.
Pereopod	Last five thoracic appendages, walking legs in decapods.
Peripheral	Structure or location distant from center, near outer boundaries.
Peristome	Around the mouth.
Pilose	Covered with setae.
Pinacocyte	Flattened cells comprising dermal epithelium in sponges.
Plankton	Floating organisms that have limited locomotory capabilities and therefore are distributed by water movements.
Pleopod (Swimmeret)	Abdominal appendages modified as copulatory structures (e.g. gonopod in male, egg brooding structure in female) or as swimming structures.
Pneumostome	The opening of the mantle cavity (lung) of pulmonate gastropods to the outside.
Polyp	The sessile stage in the life cycle of cnidarians.
Prehensile	Adapted for grasping.
Prementum	The distal part of the labium.
Proboscis	A tubular sucking or feeding organ with the mouth at the end found in planarians, leeches and lepidopteran insects.
Prognathous	Having the head horizontal and the mouthparts projecting forward.
Proleg	One of the fleshy abdominal legs of certain insect larvae.
Pronotum	The dorsal sclerite of the prothorax.
Propodus	Sixth segment of appendage, between carpus and dactylus.
Prosternum	The sternum, or ventral sclerite, of the prothorax.
Protoconch (Nuclear whorls)	At apex of shell, whorl or whorls formed by larval snail.
Protonephridia	Primitive osmoregulatory or excretory organs consisting of a tubule terminating internally with flame bulb.
Protuberance	Thing that protrudes.
Pseudocardinal tooth	The cardinal tooth in certain bivalves; cardinal tooth is not separated from lateral tooth on hinge and is somewhat irregular.
Pubescence	Covering of short, fine setae.
Punctate	Pitted or beset with punctures.

R

Radula	Rasping tongue in some molluscs.

Reniform	Kidney-shaped.
Retractor	Capable of being pushed out and drawn back in.
Retreat	Refuge or isolated place.
Rhabdite	Rodlike structures in the cells of the epidermis or underlying parenchyma in certain turbellarians. They are discharged in mucous secretions.
Rhomboid	A quadrilateral of which only the opposite sides and angles are equal.
Rostrum	A snout-like projection on the head.

S

Saccoid gill	A swollen sac-like gill.
Scent gland	A gland producing an odorous substance.
Sclerotization	Process of hardening the cuticle of arthropods by the formation of stabilizing cross-linkages between peptide chains of adjacentprotein molecules.
Scutellum	A sclerite of the thoracic notum; a mesoscutellum as a more or less triangular sclerite behind the pronotum.
Septa	Mesodermal sheet separating adjacent segments, as in annelids.
Serrate	Toothed along the edge like a saw.
Sessile	Attached or fastened, incapable of moving from place to place; attached directly, without a stem or stalk.
Seta	A needlelike chitinous structure of the integument of annelids, arthropods, and others; a bristle.
Sinistral	Left-handed; pertaining to the left; in gastropods, shell is sinistral if opening is to the left of columella when held with spire up and facing observer.
Siphon	Tubular extension of the mantle margin.
Snout	The projecting nose and mouth of an animal.
Spatulate	Spoon-shaped.
Spicule	Calcareous and siliceous skeletal formations present in the tissues of sponges.
Spiracle	External opening of a trachea in arthropods.
Spongocoel	Central cavity of sponges.
Sternum	Ventral sclerite of an abdominal segment of arthropods.
Sternite	Ventral plate of an abdominal segment.

Stipes	The second segment, or division, of a maxilla, which bears the palp, the galea, and the lacinia.
Stridulate	To make a noise by rubbing two structures or surfaces together.
Subgenital plate	A platelike sternite that underlies the genitalia.
Subimago	The first of two winged instars of a mayfly after it emerges from the water.
Supracoxal	Above the coxa.
Suture	An external line-like groove in the wall, forms a border between two adjoining whorls in gastropod shells.
Syncytium	A mass of protoplasm containing many nuclei and not divided into cells.

T

Tagmata	A compound body section of an arthropod resulting from embryonic fusion of two or more segments.
Tarsomere	A segment of tarsus.
Tarsus	The leg segment immediately beyond the tibia.
Teleconch	All shell whorls exclusive of protoconch.
Telson	The posterior part of the last abdominal segment; the posterior nonmetameric portion of the body.
Tenaculum	A minute structure on the ventral side of the third abdominal segment that serves as a clasp for the furcula of Collembola.
Tergum	Dorsal part of an arthropod body segment.
Trachea	A spirally-ringed, internal, elastic air tube in insects; an element of the respiratory system.
Trapezoidal	A quadrilateral with one pair of sides parallel.
Triploblastic	Three primary germ layers of metazoan embryo: ectoderm, mesoderm and endoderm.
Trochanter	A segment of the insect leg between the coxa and the femur.
Trochantin	A small sclerite in the thoracic wall immediately anterior to the base of the coxa.
Trochophore larva	Free-swimming larva of some snails.
Tubercle	A small knoblike rounded protuberance.
Turret (shaped)	Tower shaped.

U

Umbilicus	Depression or cavity at base of body whorl.
Umbo	The prominences on either side of the hinge region in a bivalve shells.
Urogomphi	Fixed or movable cercus-like processes on the last segment of a beetle larva.
Uropod	One of the terminal pair of lobe-like abdominal appendages.

V

Veliger	Larval form of certain molluscs; develops from the trochophore and has the beginning of a foot, mantle and shell.
Velum	A membrane on the subumbrella surface of jellyfishes of class Hydrozoa; or a ciliated swimming organ of a snail larva.
Verge	Penis; male copulatory structure often located on head of snail.
Vestigial	Small, poorly developed, degenerate, non functional.
Visceral mass	Region of dorsoposterior body of a gastropod, generally well separated from head/foot, containing most of digestive, excretory, circulation and reproduction systems.
Viviparous	Reproduction in which eggs develop within the female body.

W

Whorl	Any complete coil or exposed surface of complete coil in gastropod.

Z

Zooecium	Cuticular sheath or shell of Bryozoa (Ectoprocta).
Zooid	A single member of a colony.

Index[1]

A

1 Regular font = in text; Italic font = in key; Bold font = figure

B

C

D

E

M

N

O

Mekong River Commission

P.O.Box 6101, 184 Fa Ngoum Road, Unit 18, Ban Sithane Neua,
Sikhottabong District, Vientiane Lao PDR

Telephone: (856) 21 263 263 **Facsimile:** (856) 21 263 264
E-mail: mrcs@mrcmekong.org
Website: www.mrcmekong.org