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.

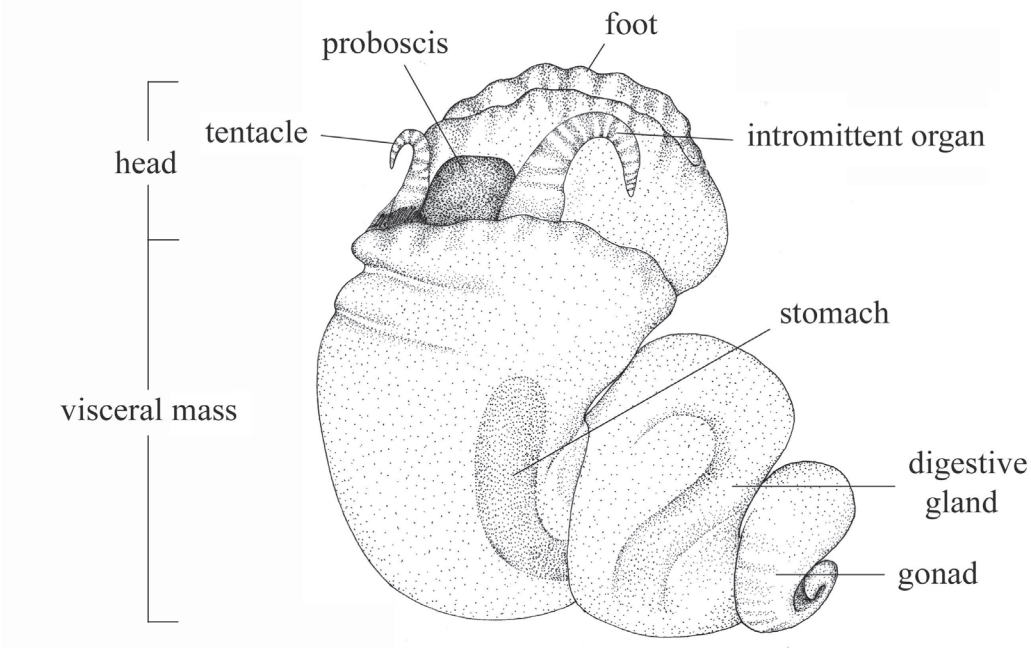
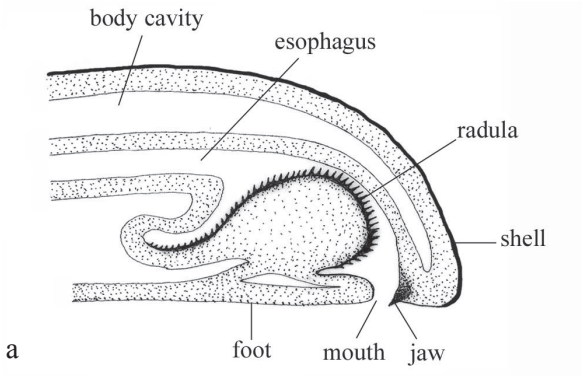


Fig. 1 View of head-foot and visceral mass of *Filopaludina* (*Siamopaludina*) sp. (Viviparidae).



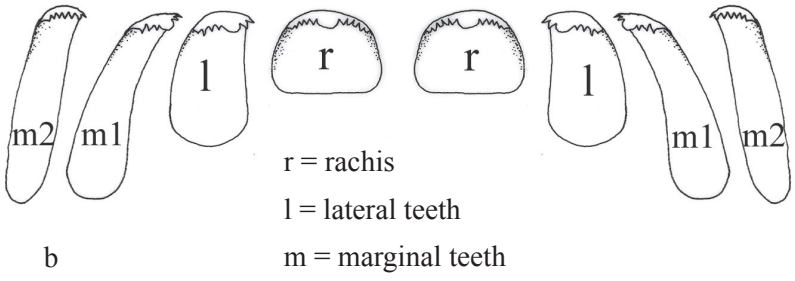


Fig. 2 a) Diagrammatic longitudinal section through the anterior end of a snail (redrawn from Pennak, 1989, fig. 5); b) structure of radula (modified from Pennak, 1989, fig. 7C).

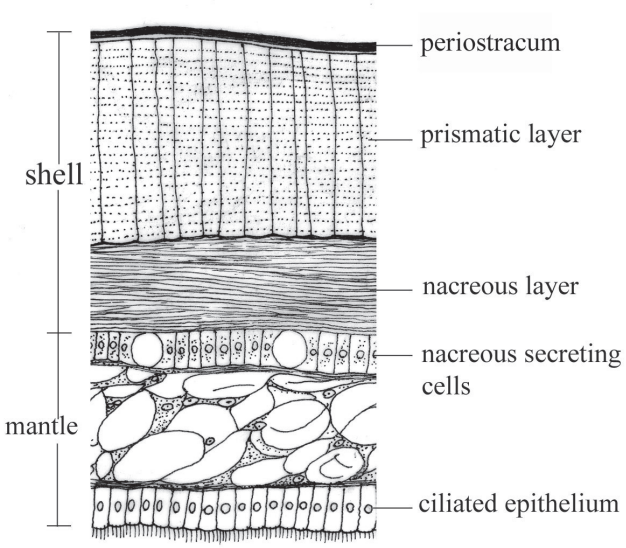


Fig. 3 Enlarged cross section of shell and mantle of freshwater clam (modified from Storer & Usinger, 1957).

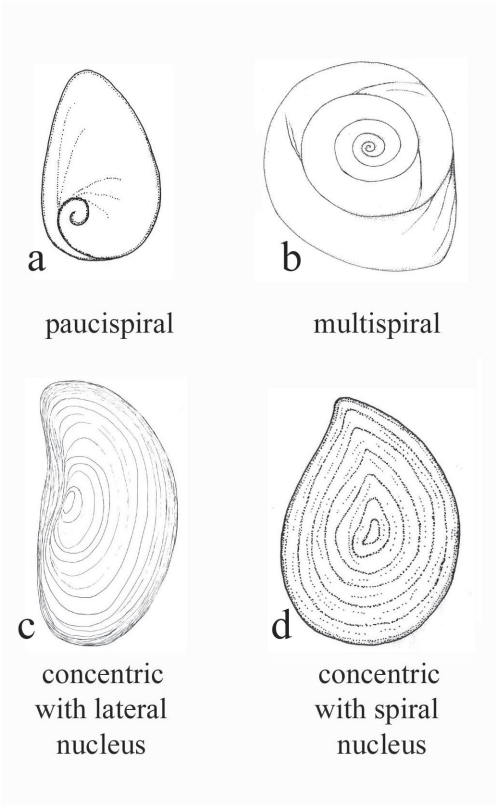


Fig. 4 Types of gastropod opercula.

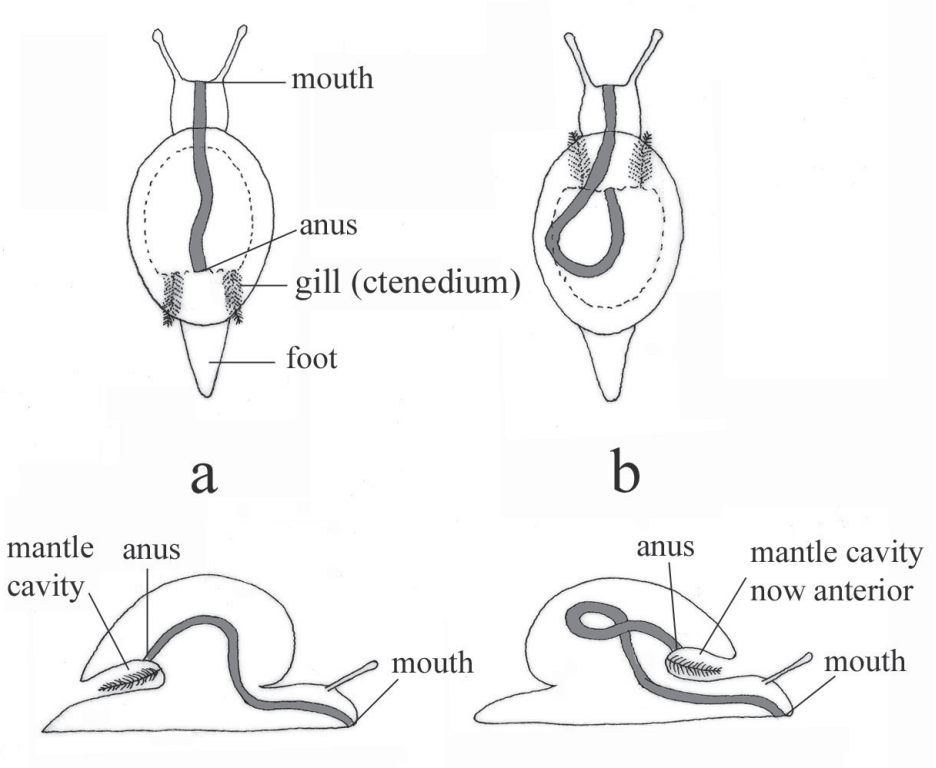
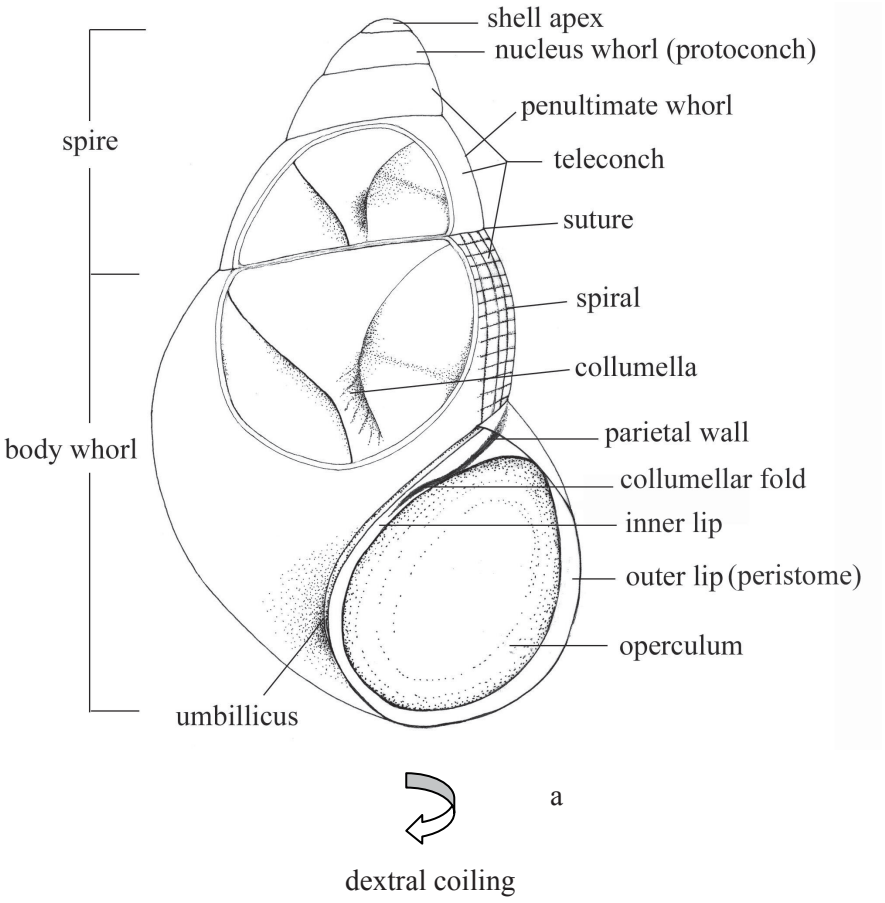


Fig. 5 Torsion in gastropods, (a) ancestral condition before torsion; (b) early gastropod, torsion complete (redrawn from Hickman & Roberts, 1995, Fig. 9.11).



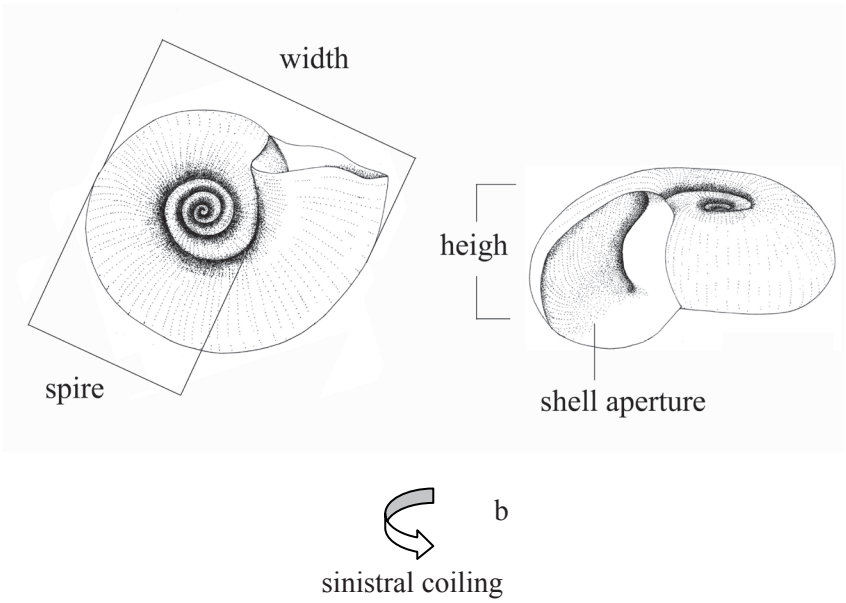


Fig. 6 a) Major external features and longitudinal section of a typical gastropod shell;
b) Discoidal shell and sinistral coiling of gastropod.

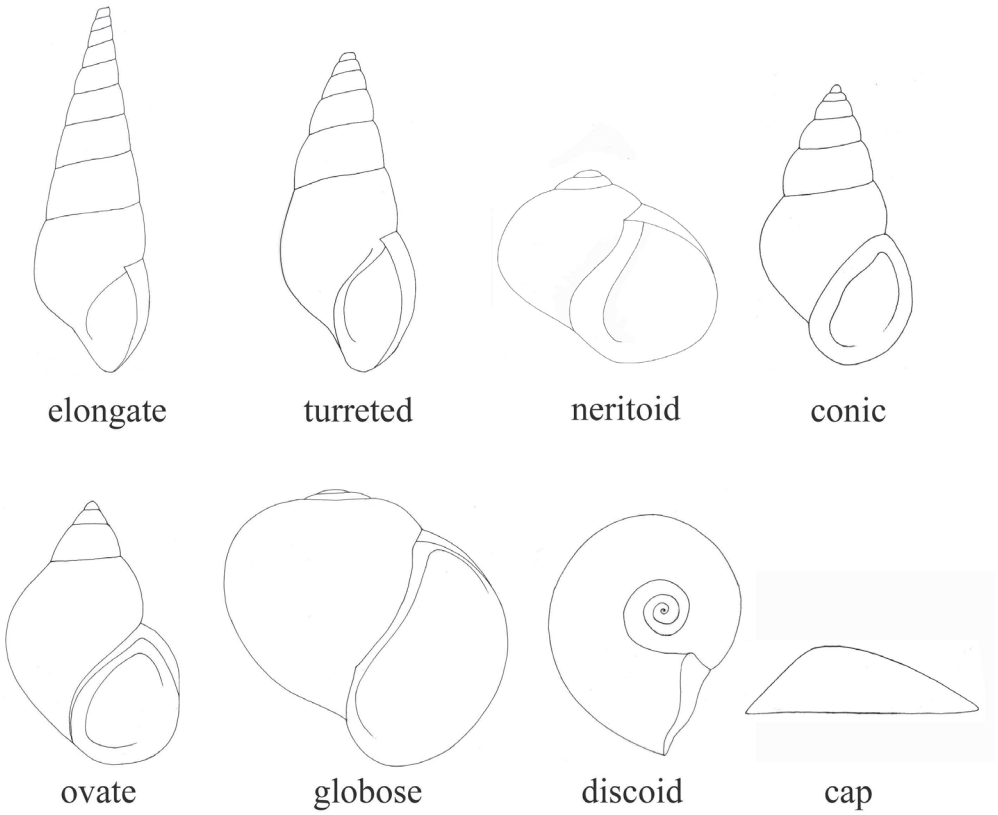


Fig. 7 Variation in shell shape in gastropods.

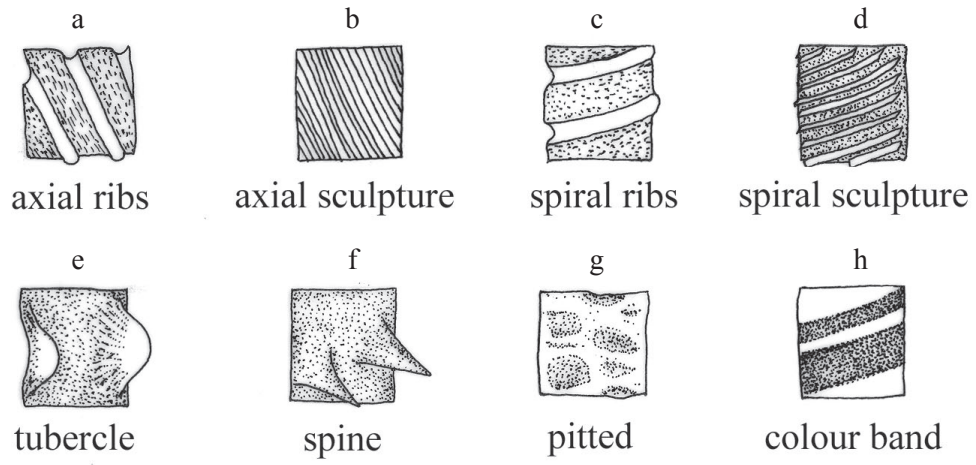


Fig. 8 Shell sculpture in gastropods.

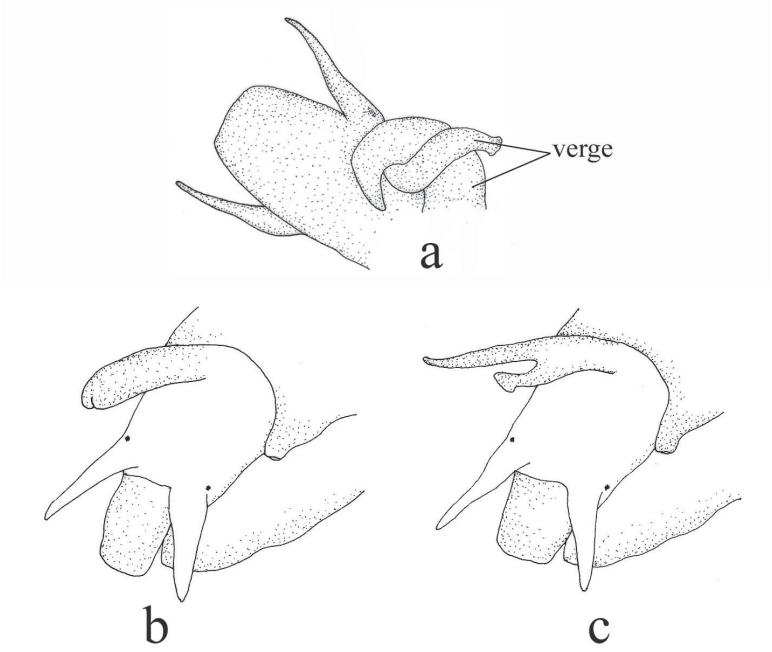


Fig. 9 Verge of Bithynidae (a); simple verge (b); and branched verge (c) of Hydrobiidae (modified from Pennak, 1989, fig. 11,13A-B).

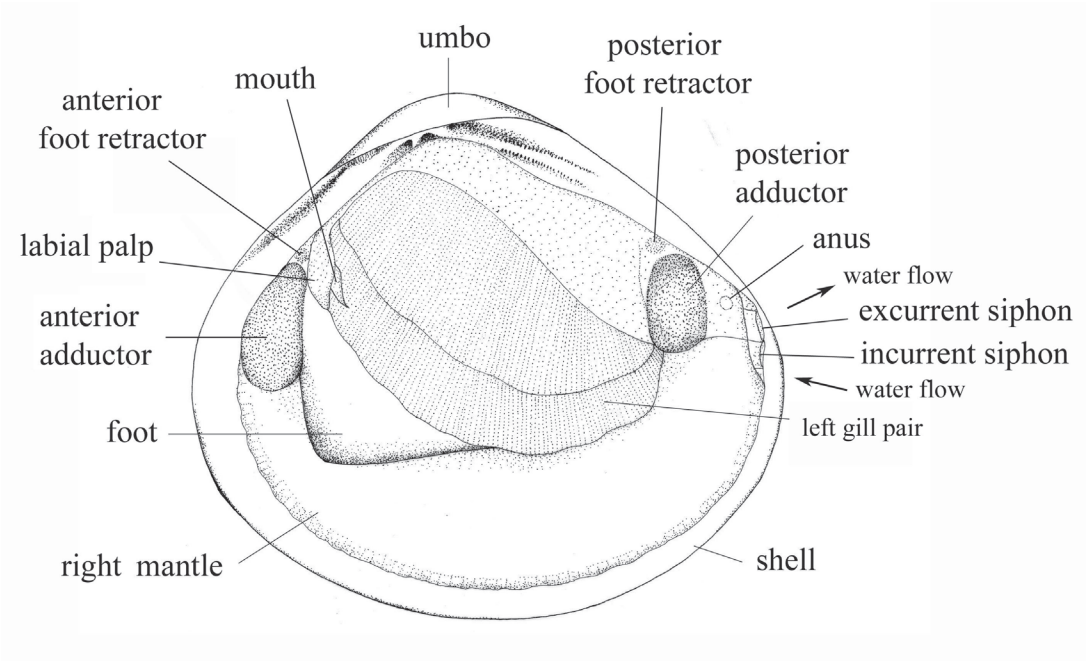


Fig. 10 Lateral view of external morphology of *Corbicula* sp. (Corbiculidae), left shell removed.

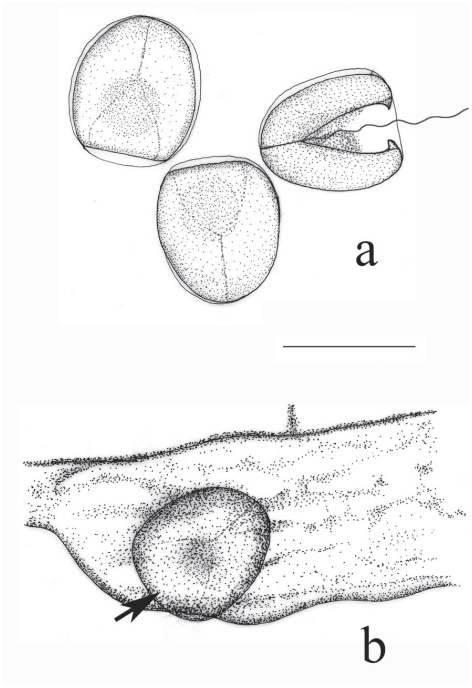


Fig. 11 Glochidia larvae of *Hyriopsis* (*Limnoscapha*) *myersiana* (a) and enclosure of a glochidium on the dorsal fin of *Helostoma temmicki* (b) (modified from Panha, 1991, fig. 1).
Scale = 25 µm.

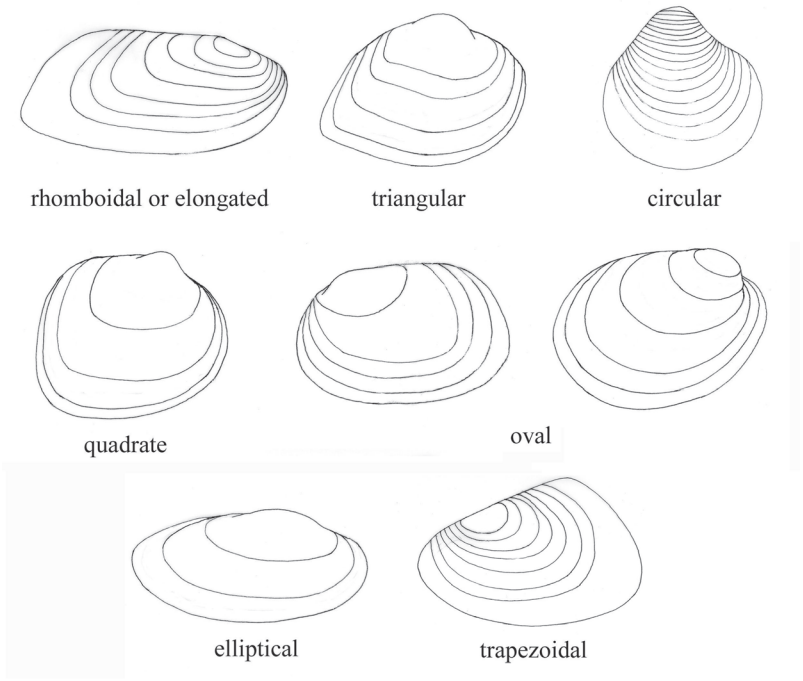


Fig. 12 Shell shapes in pelecypods.

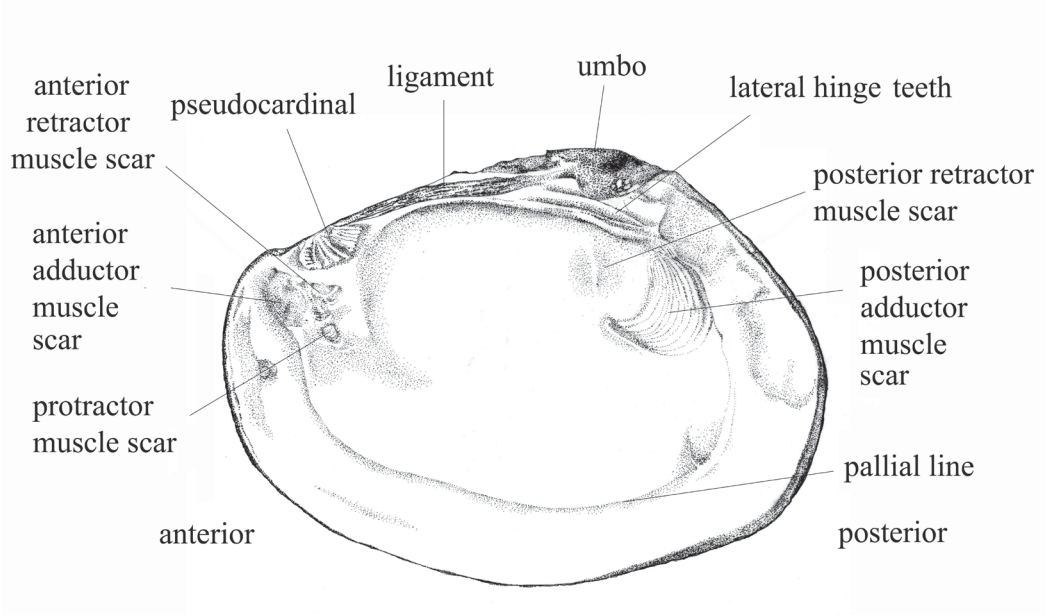


Fig. 13 *Chamberlainia hainesiana*, showing general features inside the right shell.

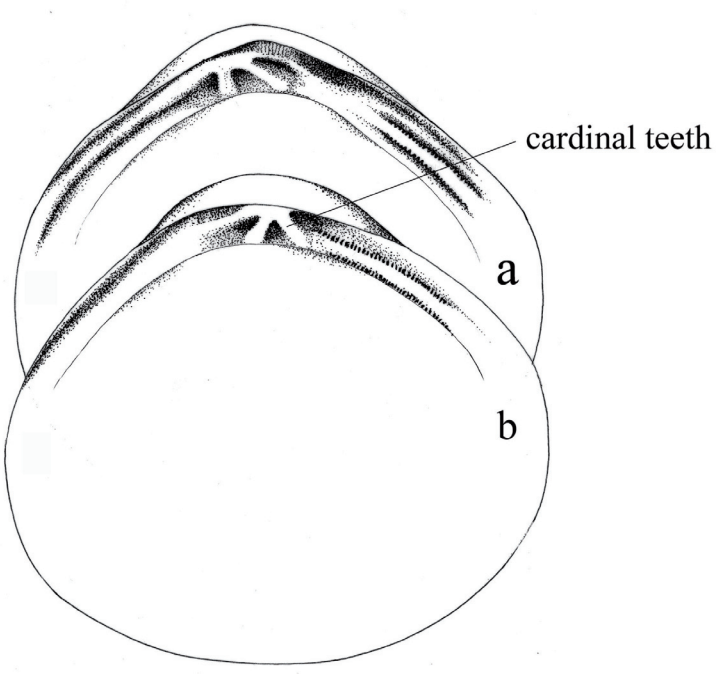


Fig. 14 Left valve (a) and right valve (b) of *Corbicula* sp.

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 ..... *funiculata*
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.

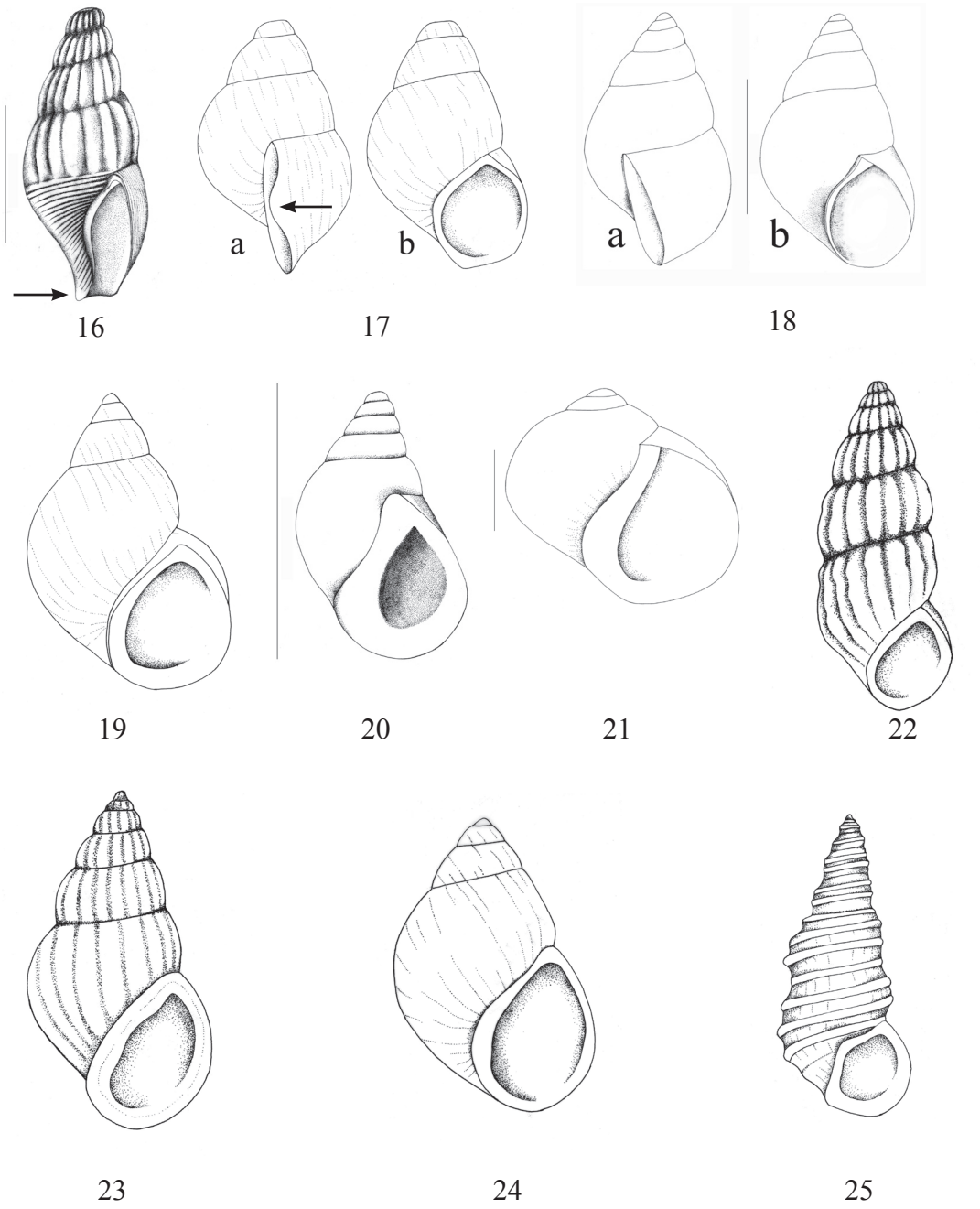


Fig. 16-25 16. Shell of *Clea* sp. (arrow indicated siphonate); 17. Side view (a) and apertural view (b) of shell of *Wattebledia* sp. arrow indicates sinuosity (redrawn from Upatham *et al*., 1983, fig. 52a-b); 18. Side view (a) and apertural view (b) of shell of *Bithynia siamensis*; 19. Shell of *Rehderiella* 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.

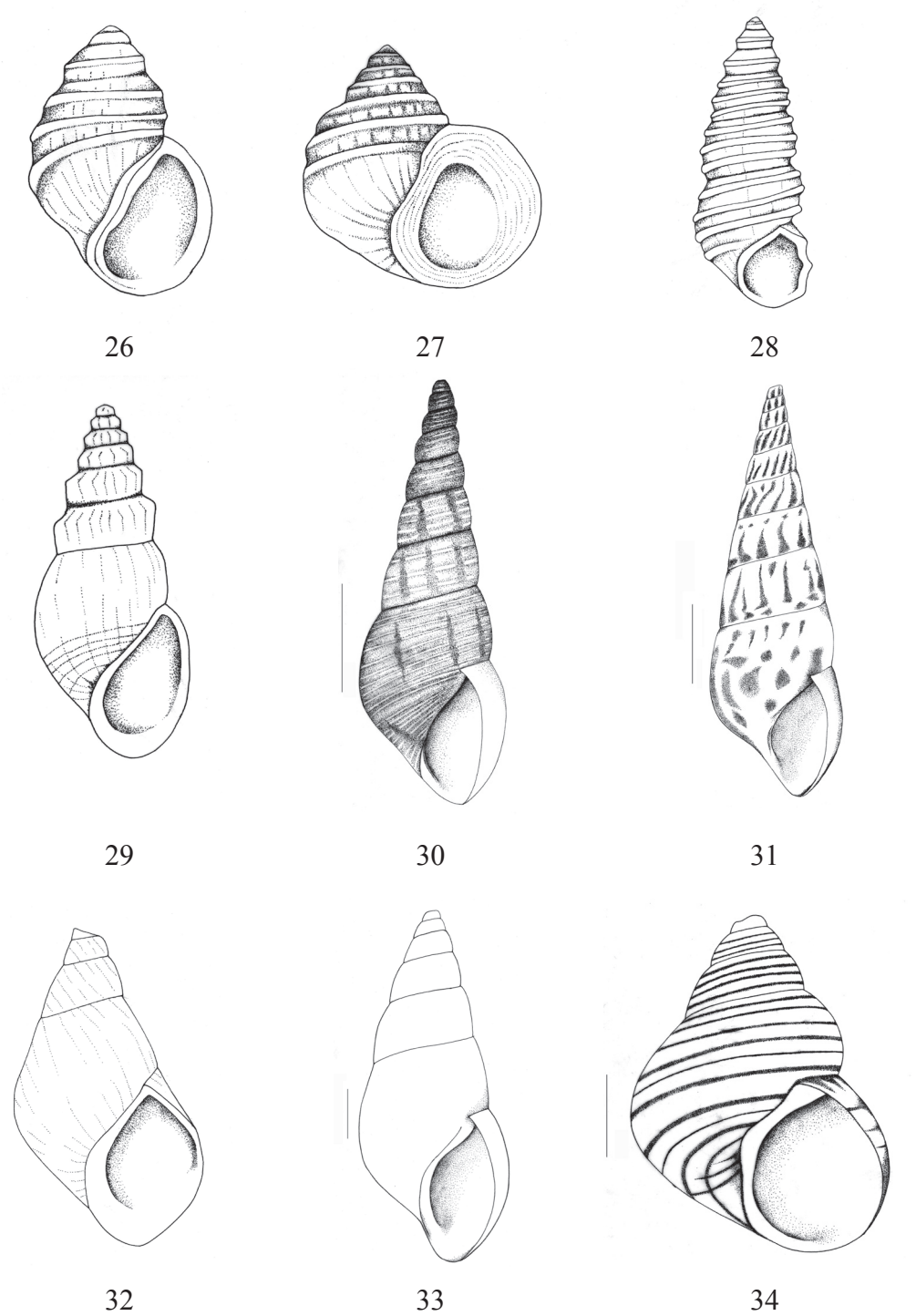


Fig. 26-34 26. Shell of *Hydrorissoia* sp. (redrawn from Upatham *et al*., 1983, fig. 67); 27. Shell of *Jullienia* sp. (redrawn from Upatham *et al*., 1983, fig. 65); 28. Shell of *Kareliania* sp. (redrawn from Upatham *et al*., 1983, fig. 68); 29. Shell of *Thiara* sp. (redrawn from Upatham *et al*., 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.

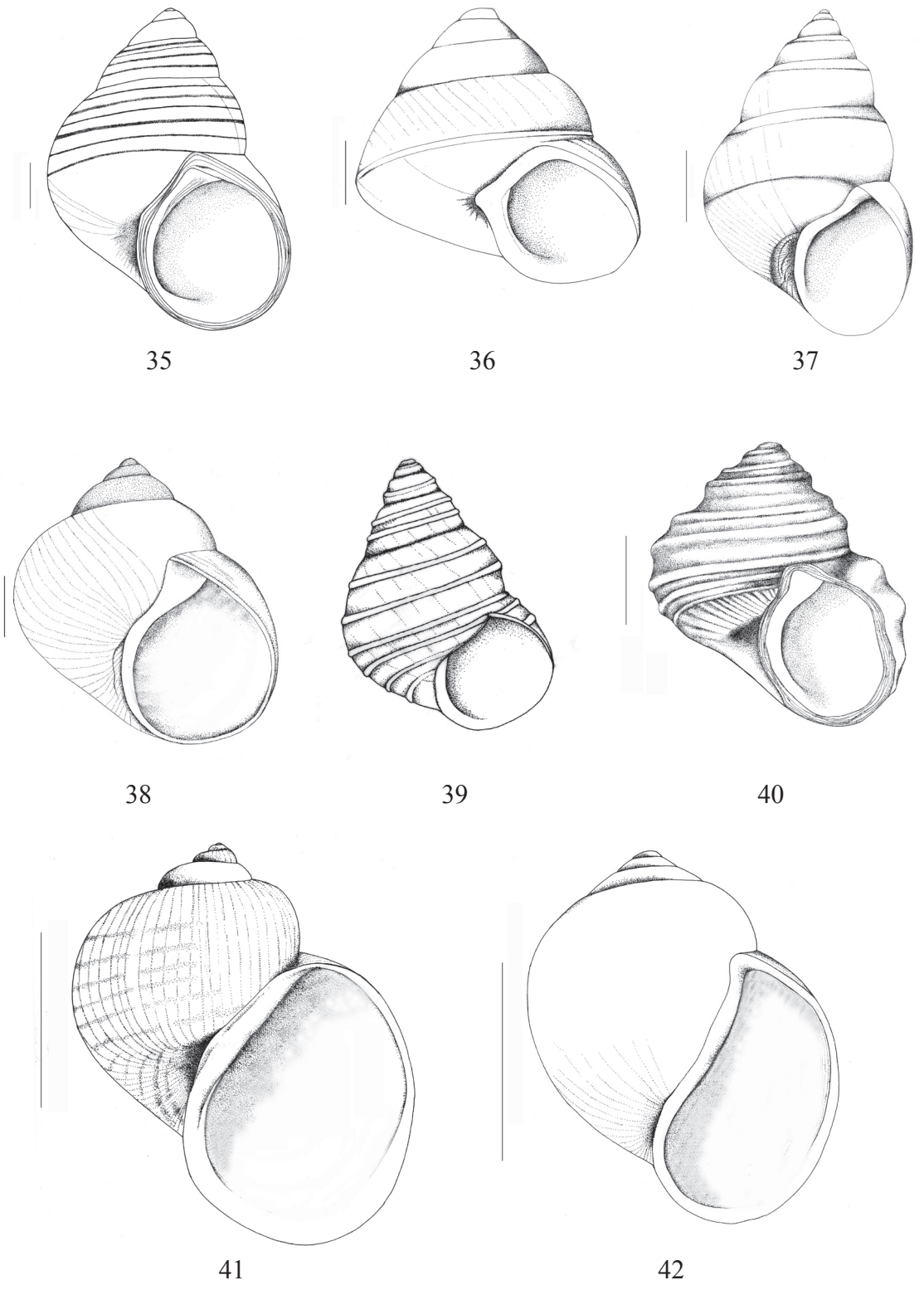
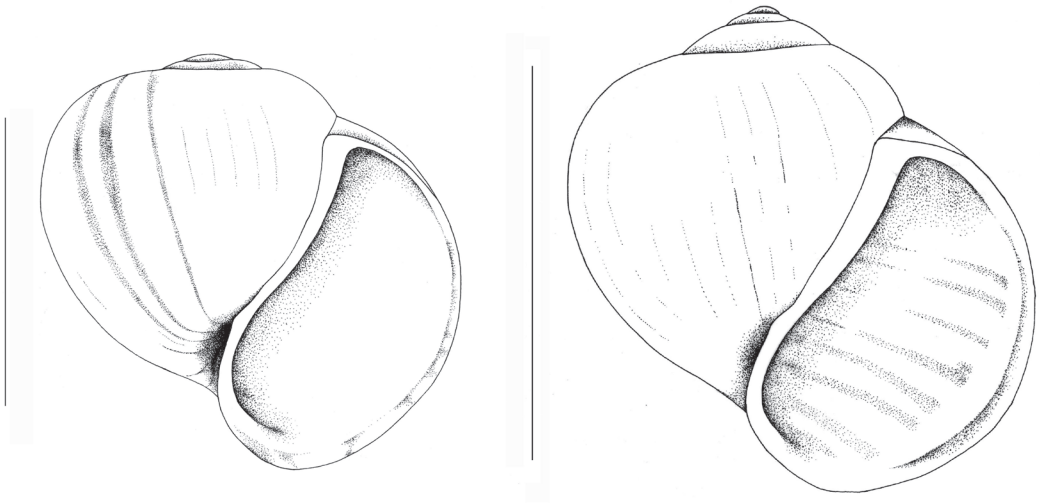


Fig. 35-42 35. Shell of *Filopaludina* (*Siamopaludina*) sp.; 36. Shell of *Trochotaia trochoides*; 37. Shell of *Idiopoma* sp.; 38. Shell of *Mekongia pongensis*; 39. Shell of *Sinotaia* sp. (redrawn from Upatham *et al*., 1983, fig. 40); 40. Shell of *Anulotaia* sp.; 41. Shell of *Pomacea* sp.; 42.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



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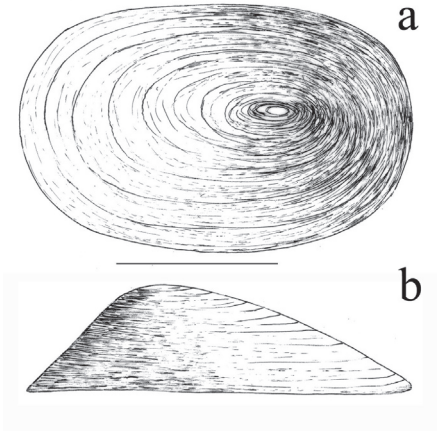

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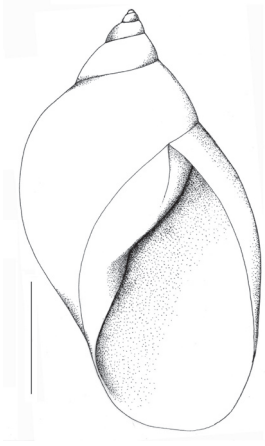
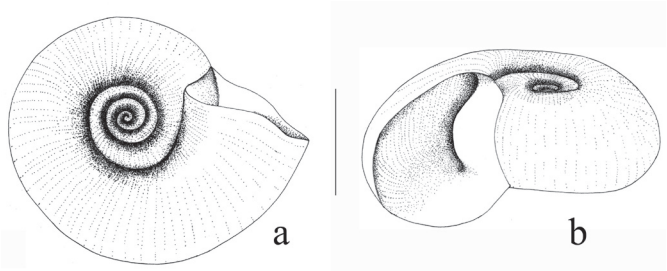




46 47

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

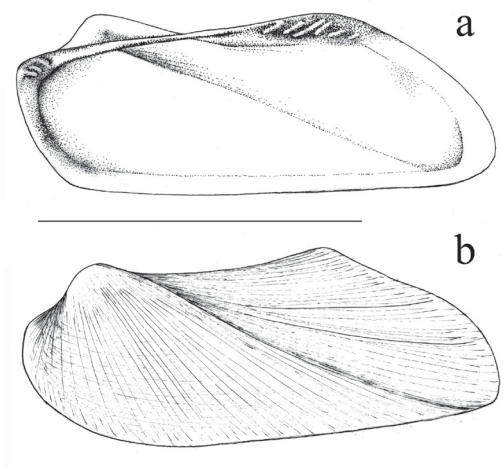
1 Shell length more than 20 mm; shell elongate, not equilateral, with pointed anterior end and round posterior ..... *S. hamandi*
1′ Shell length less than 10 mm; shell elongate triangular ..... *S. morrisoni*

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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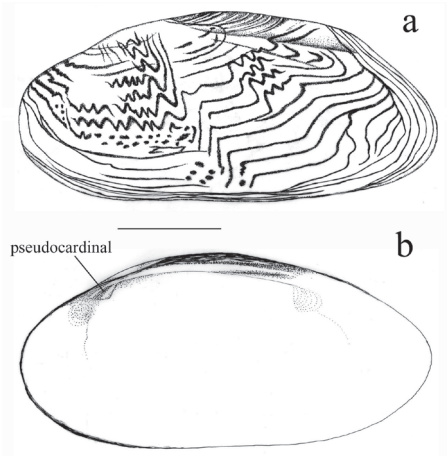

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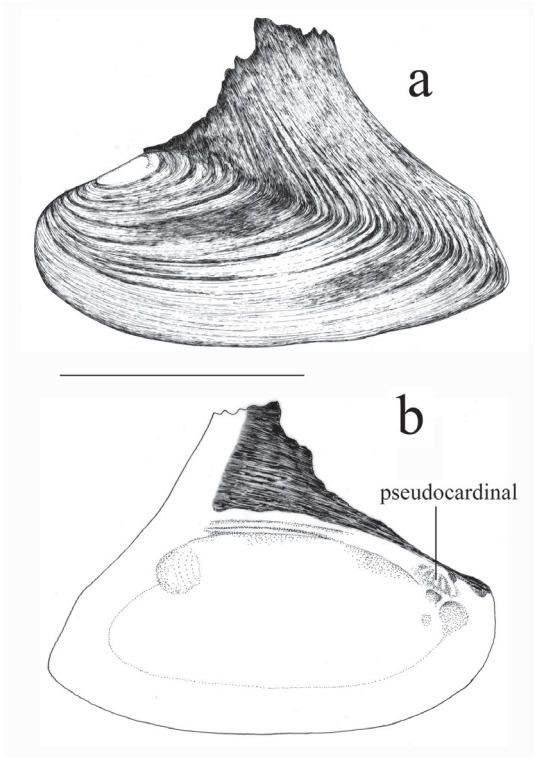

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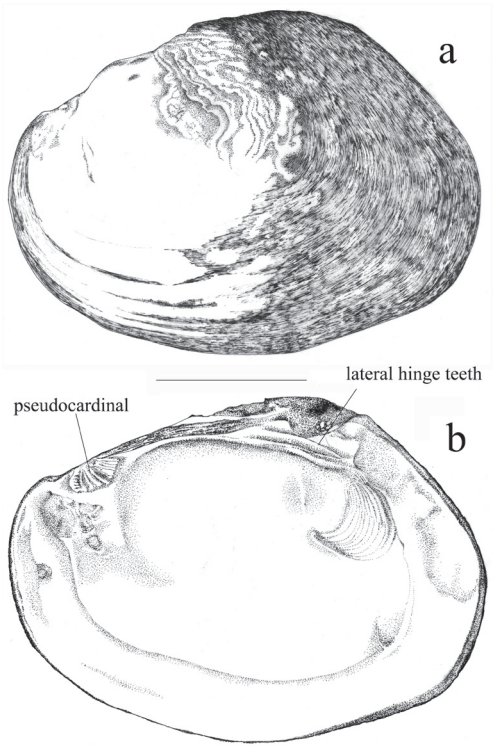
Fig. 48–51 48. Left valve (a) and right valve (b) of the shell of *Scaphula* sp.; 49. Shell of *Scabies nucleus.* 50. Left valve (a) and right valve (b) of the shell of *Scabies crispata*; 51. Left valve (a) and right valve (b) of the shell of *Hyriopsis* sp. Scale: (48-50) 5 mm; (51) 5 cm.



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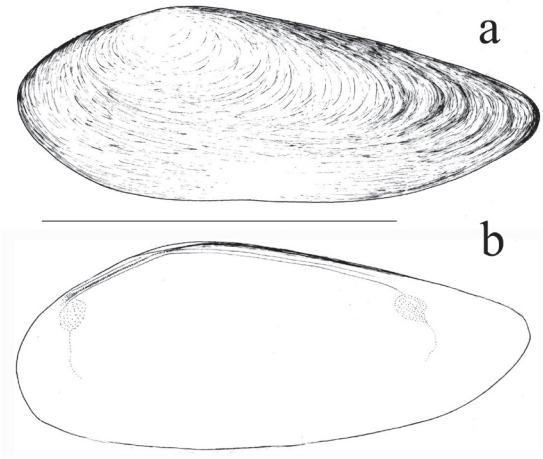

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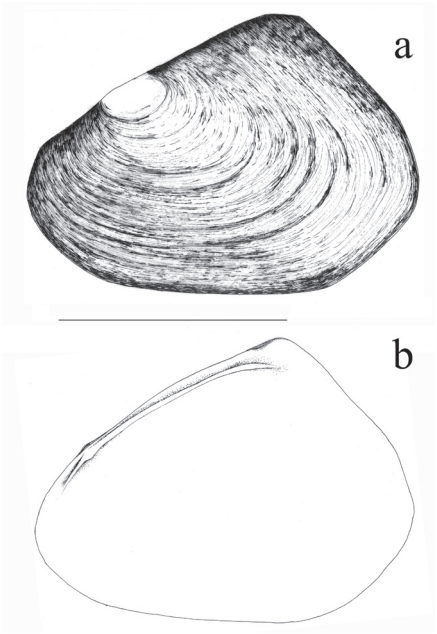

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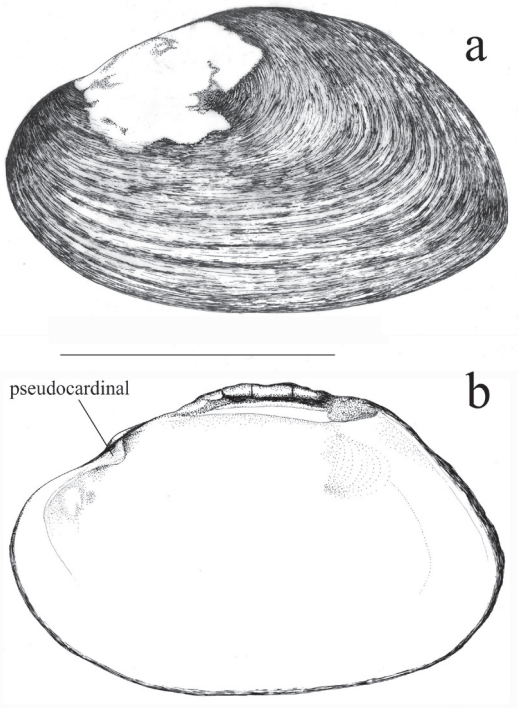

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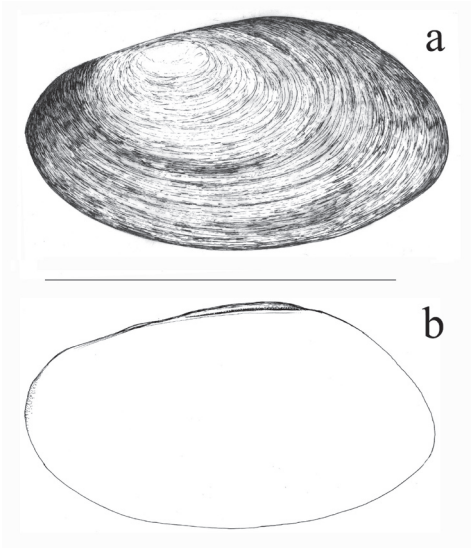
Fig. 52–55 52. Left valve (a) and right valve (b) of the shell of *Chamberlainia hainesiana*; 53. Left valve (a) and right valve (b) of the shell of *Ensidens ingallsianus*; 54. Left valve (a) and right valve (b) of the shell of *Physunio eximius*; 55. Left valve (a) and right valve (b) of the shell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



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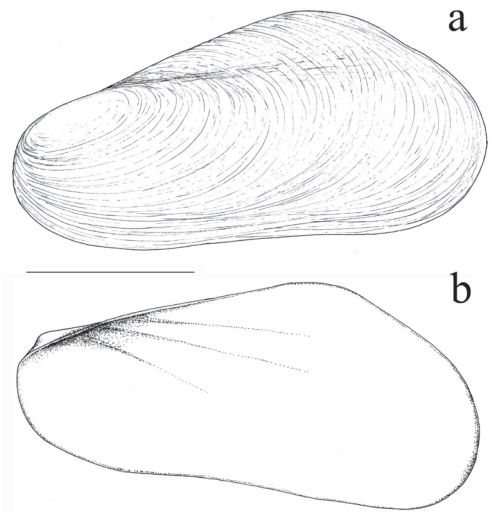

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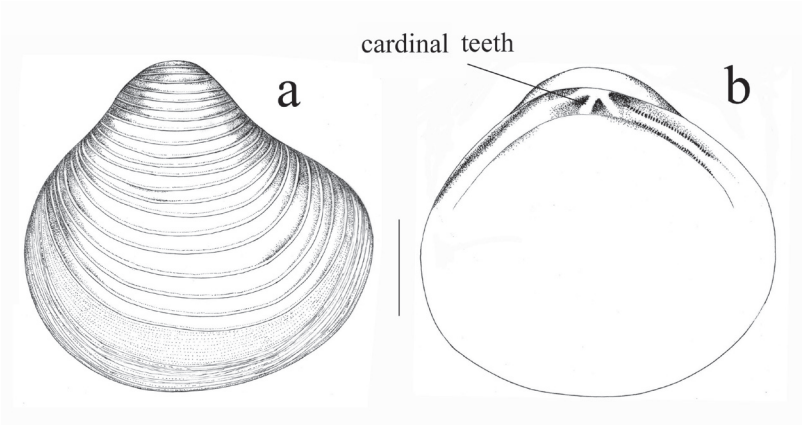

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Fig. 56-58 56. Left valve (a) and right valve (b) of the shell of *Pilsbryoconcha exilis*;
57. Left valve (a) and right valve (b) of the shell of *Limnoperna siamensis*;
58. Left valve (a) and right valve (b) of the shell of *Corbicula* sp.
Scale: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