

## COMPARATIVE ANATOMICAL STUDY OF TWO SPECIES OF *SEMELE* FROM THAILAND (BIVALVIA: TELLINOIDEA)

Luiz Ricardo L. Simone and Claudia Heromy Guimarães

Museu de Zoologia da Universidade de São Paulo,  
Caixa Postal 42494, 04299-970 São Paulo, São Paulo, Brazil.  
Email: Irsimone@usp.br

**ABSTRACT.** – An anatomical description of two semelids from Thailand is presented, based on samples from Kungkrabaen Bay, Gulf of Thailand. The species are *Semele sinensis* A. Adams, 1853, and *S. carnicolor* (Hanley, 1845), both with Indo-Pacific distributions. Morphology in these two species is typically tellinoidean, each with a long internal ligamental element (resilium), a distance between the inner fold of the mantle edge and the other two folds, long and branched gastric ducts to the digestive diverticula, and a stomach diverticulum located in the posterodorsal corner of the gastric chamber, projecting posteriorly. The main anatomical differentiation between the two species is in the character of the labial palps.

**KEYWORDS.** – Semelidae, *Semele carnicolor*, *Semele sinensis*, systematics, morphology.

### INTRODUCTION

The Semelidae is an important family of Tellinoidea, widely distributed across all oceans. The main distinctive character is the internal portion of the ligament, called the resilium (Trueman, 1953; Boss, 1982). They usually have rounded, laterally flattened shells and live in unconsolidated, mainly muddy substrata.

During the workshop Marine Mollusks Workshop of Kungkrabaen Bay, Thailand, two species of the genus *Semele* Schumacher, 1818 [type species *Semele reticulata* Schumacher, 1818, (= *Tellina proficua* Pulteney, 1799) ICZN opinion 1141 (1979)] were collected. An anatomical study was performed in them, which has the objective of magnify the knowledge on its morphology and its relevance in the systematics.

### MATERIALS AND METHODS

The specimens were collected during the field work period of the workshop. They were maintained alive in seawater during some days for live dissection. Following this, all specimens were preserved in 70% ethanol for further studies. Dissections were made under a stereomicroscope, with specimens immersed in preservative or seawater. Dissection techniques follow established standards. Digital photos of all steps of the dissections were taken. All drawings were obtained with the aid of a camera lucida. The presented measurements were obtained from selected specimens,

normally those dissected; these specimens are so labeled in the collection on the Museum of Zoology, University of São Paulo (MZSP); the measurements are, respectively, the anteroposterior length, the dorsoventral height and the laterolateral width, all expressed in mm.

The description of the first species, *Semele sinensis*, is the most complete. For the other species, the description is comparative and more focused on distinctions to decrease the length of this paper and to optimise the discussion. The same approach is used for the figures.

### SYSTEMATICS

*Semele sinensis* A. Adams, 1853  
(Figs. 1–6, 11–22)

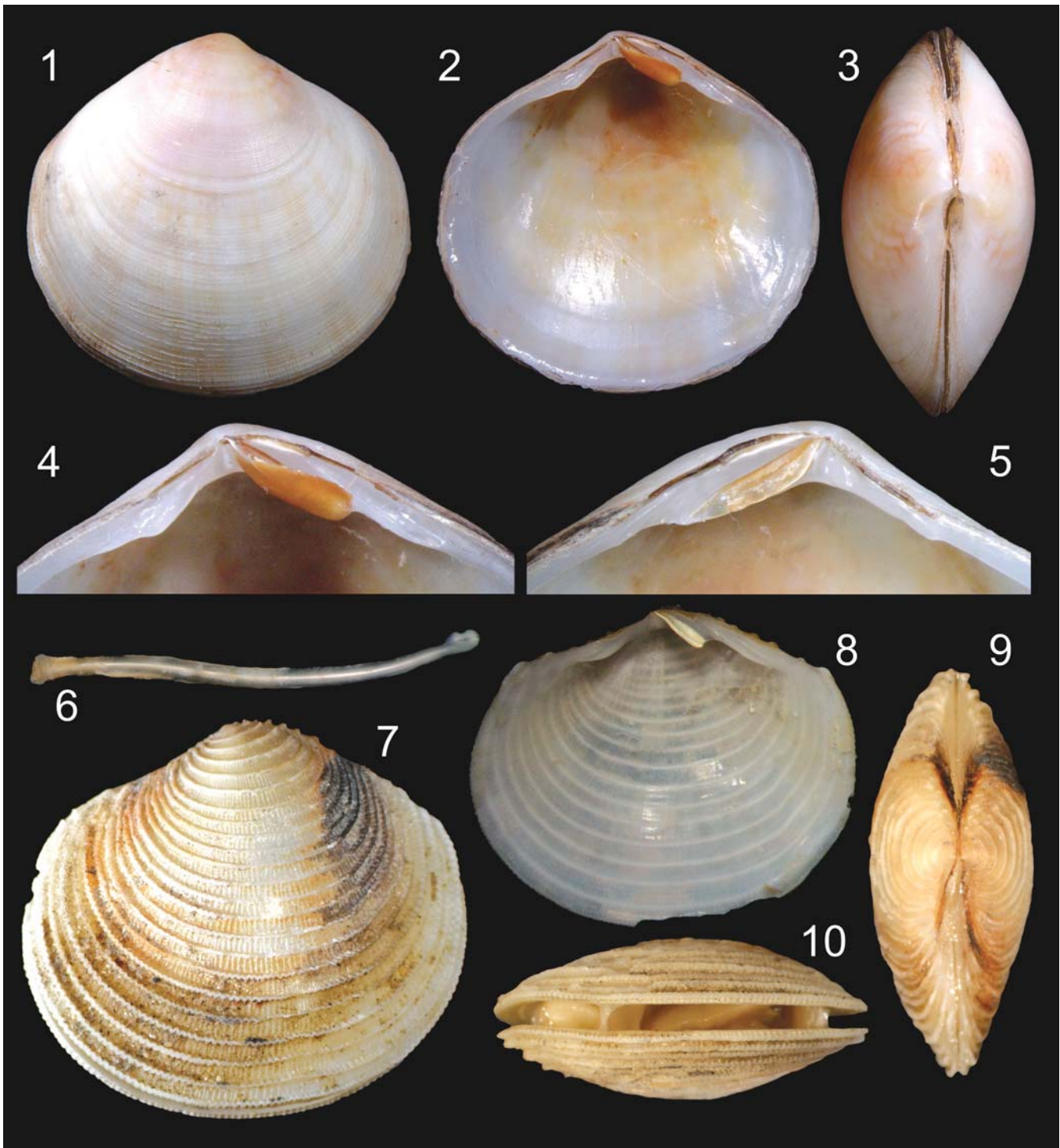
*Semele sinensis* A. Adams, 1853: 95; Bosch et al., 1995: 261, Fig. 1171; Robba et al., 2002: 102, Pl. 15, Fig. 5.  
*Amphidesma sinensis*: Reeve, 1853, Pl. 5, Fig. 28.  
For additional synonymy, see Robba et al., 2002: 102.

**Material examined.** – All Thailand, Chantaburi (Gulf of Thailand), Kungkrabaen Bay; 1 ex. (MZSP 55254), sta. KKB-07, rocky shore at Laem Ban Kung Krabaen, 12°34.932'N 101°53.147'E, coll. Taylor & Glover, Aug.2005; 1 valve (MZSP 54934), sta. KKB-09, near Chao Lao Nai, 12°31.609'N 101°55.320'E, snorkeling, coll. Simone, Aug.2005; 1 valve (MZSP 55333), sta. KKB-13, Hin Tamae, 12°32.862'N 101°54.713'E, snorkeling, coll. Simone, Aug.2005; 1 shell (MZSP 55362), sta. KKB-14, beach near scuba boat dock, 12°34.893'N 101°53.491'E, coll. Simone, Aug.2005; 2

shells (MZSP 55384), sta. KKB-15, Chao Lao Beach, 12°32.578'N 101°57.831'E, coll. Simone, Aug.2005; 1 valve (MZSP 55441), sta. KKB-19, Hin Ka Rang Daeng, 12°30.81'N 101°54.50'E, coll. Simone, Aug.2005.

**Description.** – *Shell* (Figs. 1–5): Outline somewhat circular (dorsoventral height ca. 95% of anteroposterior length); laterally flattened (width ca. half of length); walls relatively thick. Colour white to cream, with narrow radial bands randomly distributed. Umbones bluntly pointed, located

approximately in centre, weakly turned anteriorly (Figs. 1, 3). Anterior, ventral, and posterior edges forming a circle. Dorsal edge anterior and posterior to umbo somewhat straight. Sculpture uniformly commarginal, with very low scales, being somewhat taller in posterior region (Fig. 1); ca. three scales per mm, each separated from neighboring scales by space equivalent to four to five times its width. Very delicate and shallow radial furrows detectable in interspaces between scales, of width and concentration equivalent to those of commarginal sculpture, uniformly distributed over



Figs. 1–10. *Semele sinensis* shell (MZSP 55254, length 35 mm): 1, right valve, outer view; 2, inner view; 3, articulated dorsal view; 4, hinge of right valve; 5, hinge of left valve; 6, crystalline style, extracted and partially cleaned (length 20 mm). *Semele carnicolor* shell (MZSP 55609, length 13 mm): 7, left valve, outer view; 8, right valve, inner view; 9, articulated dorsal view; 10, articulated ventral view.

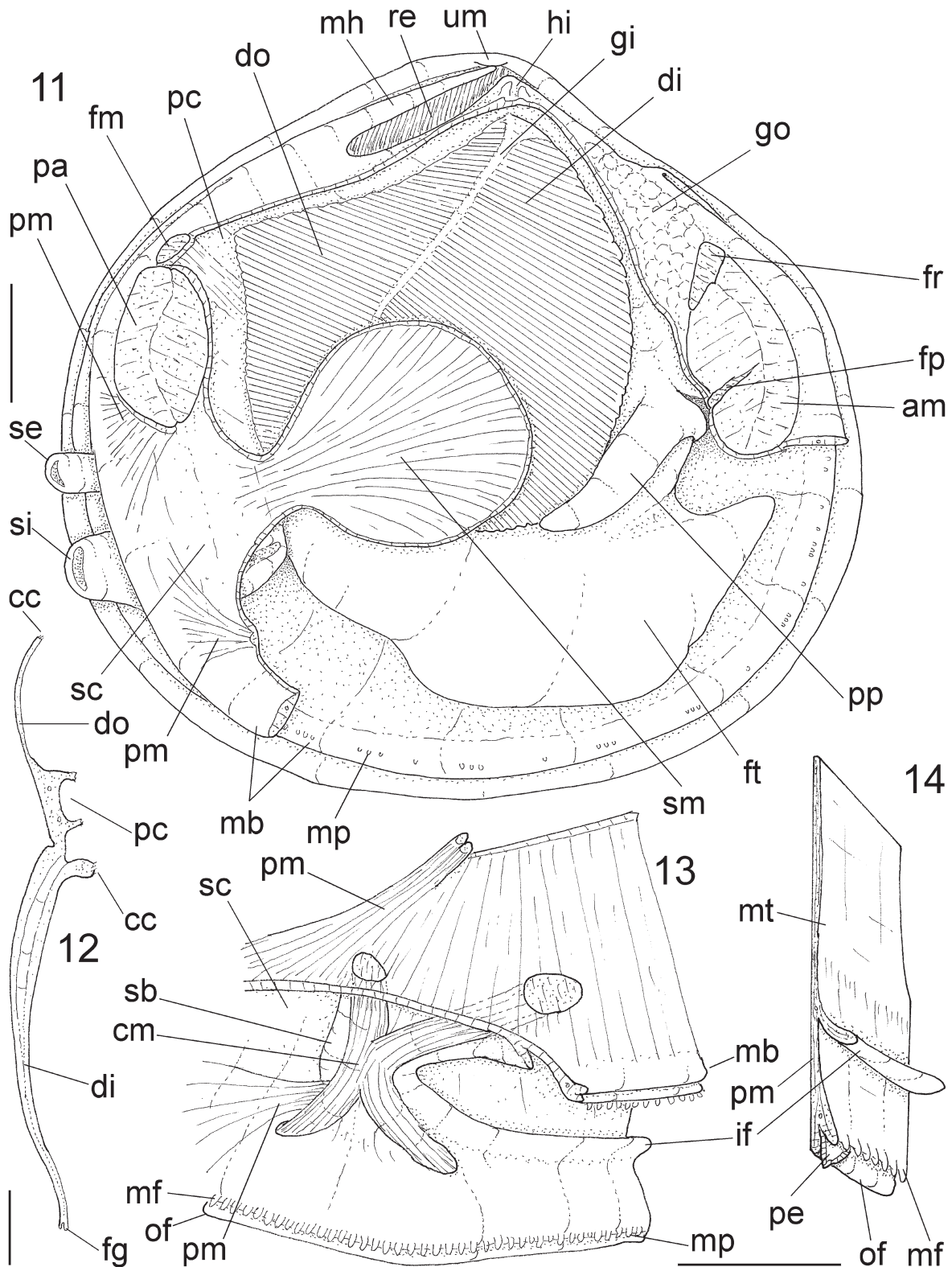
entire surface. Inner surface whitish, glossy, with brown spot in umbonal cavity (Fig. 2). Cardinal teeth restricted to infraumbonal region, comprising one tooth in right valve and two teeth in left valve, disposed divergently (Figs. 4–5). Pair of almost symmetrical lateral teeth in right valve (Fig. 4), anteroposteriorly elongated, running parallel and at short distance from dorsal shell edge; each lateral tooth at ca. dorsal third of distance between umbo and posterior or anterior end; respective lateral sockets in left valve, possessing small tooth (ca. one third of length of lateral tooth of right valve) in anteroventral edge (Fig. 5). Ligament with external component, narrow and thin; inner element (resilium) of ca. half of hinge length, extending towards ventral and posterior (Figs. 2, 4–5). Muscle scars very shallow (Fig. 2). Scar of anterior adductor muscle elliptical, dorsoventrally elongated, with dorsal end pointed, ventral edge rounded, occupying ca. one twentieth of inner valve surface, at short distance from anterior edge. Scar of posterior adductor muscle on opposite side and of ca. 90% of size of anterior scar. Pallial line somewhat pointed posteriorly. Pallial sinus wide, forming an arch of ca. one third of size of valve, extending at some distance from anterior adductor muscle scar (Fig. 2). Scar of cruciform muscle in pallial line parallel to mantle edge, vertically below posterior adductor muscle, at posteroventral end of pallial sinus.

Main muscle system (Figs. 11, 15): Anterior adductor muscle oval in cross section, dorsoventrally elongated, situated weakly obliquely, parallel to and at short distance from shell edge; area equivalent to one twentieth of shell area; ventral edge rounded, dorsal edge somewhat pointed; positioned slightly dorsal to mid-level of shell dorsoventral distance; two elements of anterior adductor muscle separated by dorsoventral, arched virtual line, with anterior element ca. half area of posterior element. Posterior adductor muscle elliptical in cross section, located in posterior region opposed to, and at same dorsal level as anterior adductor muscle; occupying ca. 90% of area of anterior adductor muscle; two elements of posterior adductor muscle of similar size, separated by dorsoventral, central virtual line. Two anterior pairs of pedal muscles. Pair of pedal protractor muscles disposed anteroposteriorly, originating at mid-level of posterior surface of anterior adductor muscle, penetrating ca. 70% of adductor muscle width, in area ca. one fiftieth of this adductor muscle; running towards posterior, splaying fan-like in central and ventral regions of visceral sac lateral walls, thicker ventrally. Pair of anterior pedal retractor muscles disposed dorsoventrally, weakly thicker than protractor muscles; originating just dorsal to anterior adductor muscle, amidst its dorsal tip to mid-level of its posterior edge (close to origin of pedal protractors), in approximate area one tenth of that of anterior adductor muscle, being thicker dorsally and gradually narrowing towards ventral; after origin extending ventrally, slightly posterior between protractor muscles, splaying over anterior surface of visceral sac and foot, becoming thicker, bulging inside visceral cavity. Pair of posterior pedal retractor muscles of equivalent size to anterior pedal retractor muscles and disposed on opposite side; originating just dorsal to posterior adductor muscle, in an oval area equivalent to one tenth of that of adductor

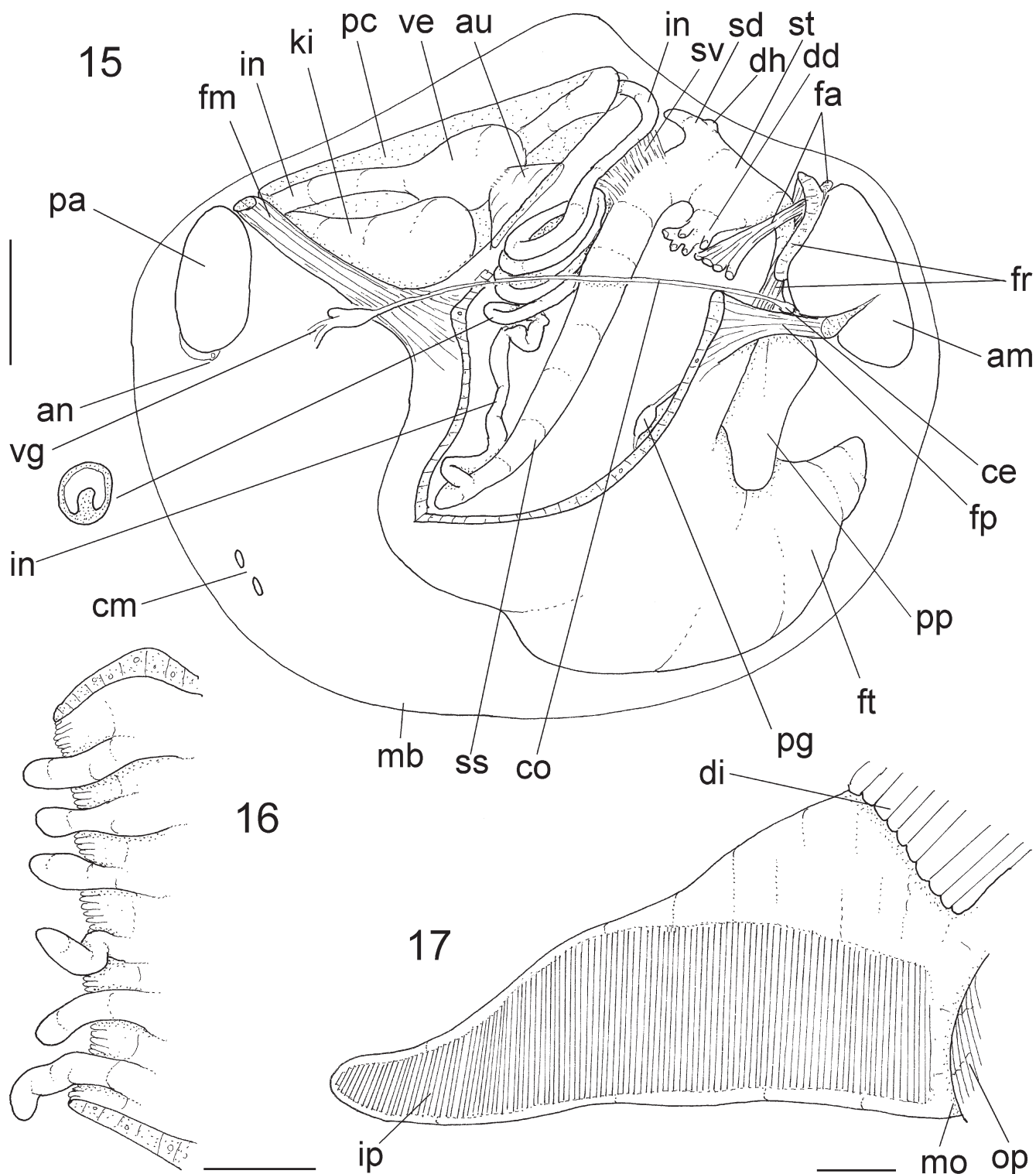
muscle; extending anteriorly and ventrally, initially at some distance from each other, gradually becoming close together and running attached to each other to integument, splaying over posterior and ventral region of visceral sac and foot, bulging in visceral cavity. No detectable cardinal muscle. Pair of branchial muscles also undetectable. Pair of siphonal retractor muscles originating in pallial sinus, with fibers directed radially towards lateral side of intersection of incurrent and excurrent siphons (Fig. 11); after this, extending along both siphons, splaying over their walls as thin longitudinal layer of muscles. Cruciform muscle of total length ca. 80% of width of posterior adductor muscle (Fig. 13, cm), located close to ventral shell edge, just anterior to horizontal level of posterior adductor muscle; anterior branch ca. twice as long and more obliquely disposed than posterior branches.

Foot and byssus (Figs. 11, 15): Foot flattened, of ca. one quarter of shell volume when retracted; distal tip pointed. Byssus absent.

Mantle (Figs. 11, 13–14, 16): External regions of mantle edge lacking pigment. Mantle edge trifolded (Figs. 13–14); outer fold flattened, ca. half of shell thickness; periostracum attached to inner surface of outer fold (Fig. 14, pe); middle fold slightly thicker than outer fold, of same height; inner fold ca. twice as tall as outer fold, located far from mantle border at distance equivalent to three to four times outer fold height. Mantle edges mostly free from each other, except at siphonal chamber (Figs. 11, 13). Middle fold entirely possessing a series of narrow, uniformly distributed papillae (Figs. 13, 14, mp); each papilla of ca. height of middle fold, ca. four times longer than wide, with rounded tip, separated from each other by distance equivalent to one papillar width. Incurrent and excurrent siphons totally separated from each other except at their base (Fig. 11); incurrent siphon somewhat thicker and larger than excurrent siphon. Inner surface of siphons smooth. Tip of incurrent siphon bearing six papillae (Fig. 16); equally distributed along tip, of height ca. one third of siphonal width, ca. four to five times longer than wide, with rounded tips, separated from each other by distance equivalent to twice papillar width; siphonal edge between papillae possessing five or six secondary papillae, as miniatures (ca. one-twentieth) of larger papillae, disposed only on edge. Excurrent siphon lacking papillae. Siphonal chamber composed of inner mantle edge fold, thin, translucent (Fig. 11), occupying ca. one tenth of shell volume; both siphons totally retractable inside chamber; with two apertures: siphonal aperture posterior, branchial aperture posterodorsal (covered by gill, connected by cilia). Pair of retractor muscles of lateral walls of siphonal chamber as two bundles (Figs 11, 13, pm), extending along distance equivalent to one tenth of total valve length, extending directly towards posterior, with divergent fibers immersed in mantle; dorsal element slightly wider than ventral element, narrow at origin, surrounding almost entire ventral edge of posterior adductor muscle in an area equivalent to one thirtieth of adductor muscle; ventral element originating in two or three small areas dorsal to cruciform muscle, with origin area equivalent to ca. one fifth of dorsal element.



Figs. 11–14. *Semele sinensis* anatomy: 11, Whole right view, right valve and part of right mantle lobe removed; 12, gill, transverse section at mid-region; 13, mantle edge in region of cruciform muscle, ventral and slightly right view, with some portions of right mantle lobe removed; 14, mantle edge, transverse section of ventral portion at mid-region. am, anterior adductor muscle; cc, ciliary gill connection; cm, cruciform muscle; di, inner demibranch; do, outer demibranch; fg, gill food groove; fm, posterior foot retractor muscle; fp, foot protractor muscle; fr, anterior foot retractor muscle; ft, foot; gi, gill; go, gonad; hi, hinge; if, inner fold of mantle border; mb, mantle border; mf, middle fold of mantle border; mh, mantle portion in hinge; mp, mantle papillae; mt, mantle; of, outer fold of mantle border; pa, posterior adductor muscle; pc, pericardium; pe, periostracum; pm, pallial muscles; pp, labial palp; re, internal element of ligament (resilium); sb, siphonal membrane; sc, siphonal chamber; se, excurrent siphon; si, incurrent siphon; sm, siphonal retractor muscle; um, umbo. Scale bars: Fig. 10 = 5 mm; remaining = 2 mm.



Figs. 15–17. *Semele sinensis* anatomy: 15, Visceral structures as in situ, right view, with topology of some adjacent structures and detail of a transverse section of indicated region of intestine also shown; 16, incurrent siphon, inner view, detail of tip opened longitudinally; 17, inner hemipalp and some adjacent structures, right view. am, anterior adductor muscle; an, anus; au, auricle; ce, cerebral ganglia; cm, cruciform muscle; co, cerebrovisceral connective; dd, ducts to digestive diverticula; dh, dorsal hood; di, inner demibranch; fa, middle-anterior accessory foot retractor muscle; fm, posterior foot retractor muscle; fp, foot protractor muscle; fr, anterior foot retractor muscle; ft, foot; in, intestine; ip, inner hemipalp; ki, kidney; mb, mantle border; mo, mouth; op, outer hemipalp; pa, posterior adductor muscle; pc, pericardium; pg, pedal ganglia; pp, labial palp; sd, stomach diverticulum; ss, style sac; st, stomach; sv, stomach microvillousities; ve, ventricle; vg, visceral ganglia. Scale bars: Fig. 15 = 5 mm; Fig. 16 = 1 mm; Fig. 17 = 2 mm.

Cruciform muscle as described above, located at anteroventral end of siphonal chamber. Mantle inner fold fusing with its counterpart along posterior surface of anterior branches of cruciform muscle, like a septum (Fig. 13, sb).

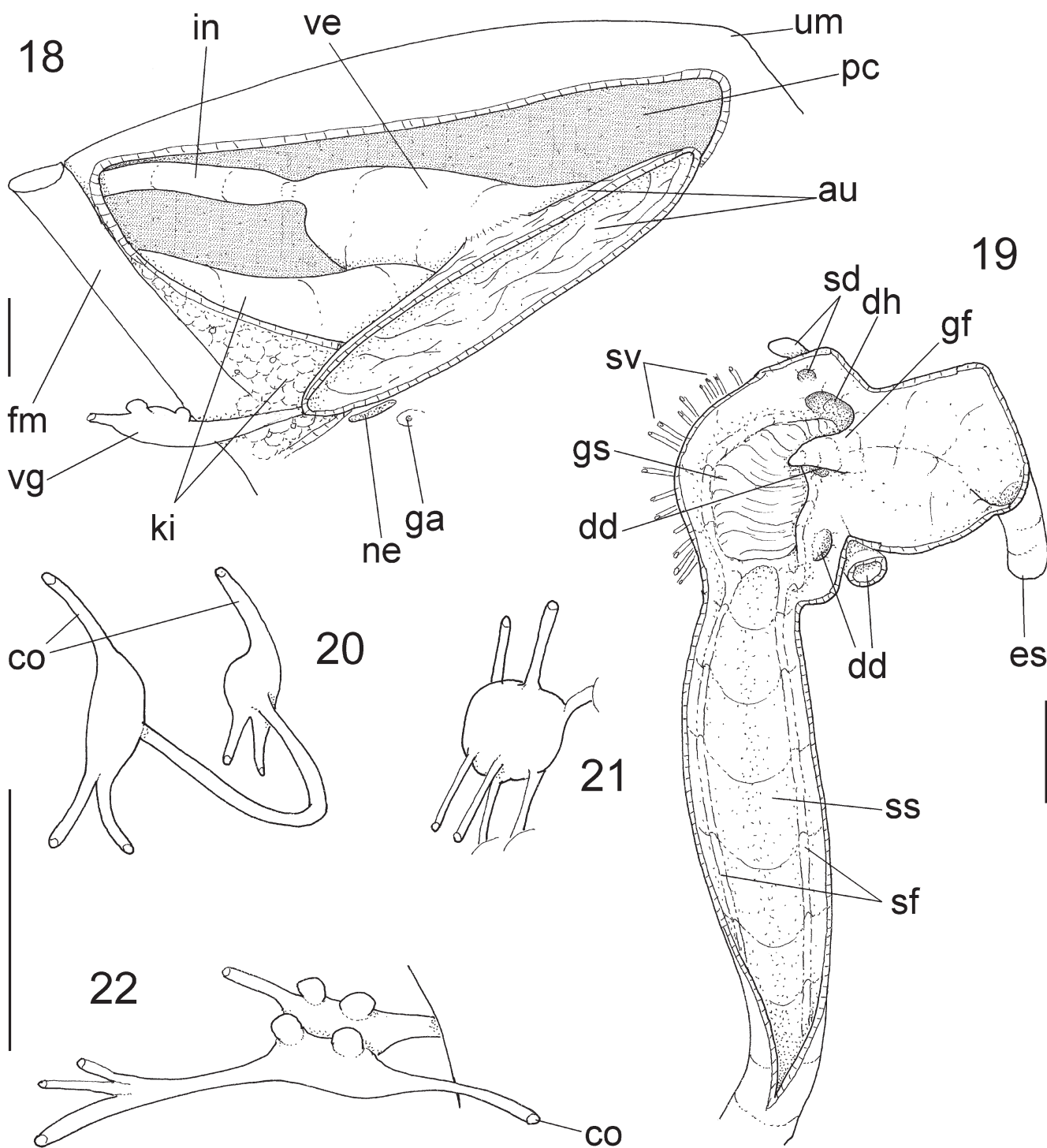
Pallial cavity (Fig. 11): Transverse area equivalent to five-sixths of that of valve, excluding both adductor muscles and narrow portion of visceral mass, extending from anterior adductor muscle to umbonal region. Labial palps somewhat triangular (Fig. 11; pp); each hemipalp similarly sized, of ca. one twentieth of valve area. Intersection of hemipalps attached to visceral mass at its anterodorsal edge; distance from anterodorsal valve edge equivalent to one fiftieth of dorsoventral valve height. Outer surface of palps smooth. Inner surface (Fig. 17) possessing transverse, dorsoventral folds; smooth (lacking folds) area surrounding each entire hemipalp edge, this area mostly equivalent in width to three folds of palp; smooth area becoming gradually wider dorsally, becoming ca. half of total width of hemipalp in region close to base. Each palp fold extremely narrow. Palp ca. three times longer than wide. Gills (Fig. 11) ca. one third of valves area; length ca. two-thirds of total shell length; height slightly longer than half of shell; narrowing gradually towards posterior. Outer demibranch positioned dorsal to inner demibranch (Figs. 11–12), triangular, with anterior end sharply pointed, located at same level as inner demibranch; outer demibranch middle portion wider, occupying ca. half of total gill width, gradually decreasing posteriorly. Outer demibranch with a single lamella covering adjacent region of visceral mass and pericardium (Fig. 12); dorsal edge connected by row of cilia surrounding dorsal edge of pallial cavity (cc); ventral edge connected to inner demibranch, also to ctenidial vein and auricle; posterior third connected laterally to anterodorsal wall of siphonal chamber aperture. Inner demibranch positioned ventral to outer demibranch; possessing descending and ascending branches covering visceral mass (Fig. 12; di); branches connected with each other by narrow septum (equivalent to half of filament width), with outer tissue connection to outer demibranch and pericardial structures; inner connection consisting of row of cilia on visceral sac, extending short distance ventral to outer connection; food groove along ventral edge of inner demibranch (Fig. 12; fg); posterior half of inner demibranch connected medially by tissue with its counterpart. Gill muscle inconspicuous.

Visceral mass (Figs. 15, 18): Visceral sac occupying ca. half of total visceral-foot mass, flattened laterally, longer dorsoventrally, somewhat triangular. Anterior and posterior walls relatively compressed by pedal retractor muscles. Anterodorsal third filled with brown digestive diverticula; remaining space filled with pale cream gonad. Stomach-style sac lying vertically along middle portion of visceral mass.

Circulatory and excretory systems (Fig. 18): Pericardial structures lying in dorsal region of visceral mass from umbonal cavity to posterodorsal surface of posterior adductor muscle, anteroposteriorly elongated, occupying ca. one quarter of total visceral volume. Pair of auricles anteroposteriorly elongated, connected to anterior and middle

thirds of gills; auricle walls thin, transparent. Ventricle surrounding ca. half of intestine passing through pericardium; connection to auricles in middle region of its ventrolateral walls, narrow, anteroposteriorly elongated. Kidney beige, solid, elongated, located in inferior-posterior quarter of pericardium, additionally surrounding both posterior retractor muscles of foot. Nephropore anteroposteriorly elongated, located subterminally in anterior region of kidney (Fig. 18; ne) in suprabranchial chamber of inner demibranch.

Digestive system (Fig. 15): Labial palps as described above. Mouth with relatively thick lips, internally smooth, lacking folds. Oesophagus long, narrow, dorsoventrally flattened, with anterior end touching posterior end of anterior adductor muscle, extending directly dorsal a distance equivalent to one third of anterior adductor muscle length, immersing in digestive diverticula; inner surface smooth. Stomach oval, anteroposteriorly elongated, located anterior to umbones, of ca. half of visceral sac length and one quarter of its height; pair of ducts to digestive diverticula located ventrolaterally, posterior to oesophageal insertion, both directed ventrally; each constituting a chamber of ca. one eighth of stomach volume, with six or seven relatively wide secondary ducts, mostly turned posteriorly. Gastric diverticulum in right-posterior region of gastric dorsal surface, extending as a weak arch towards posterior, along a distance equivalent to one-quarter of stomach length; inner surface smooth. Dorsal hood (dh) of ca. half length and twice width of gastric diverticulum, located in dorsal-left region of gastric chamber, somewhat opposed to diverticulum, hemispherical in general form; inner surface smooth. Well-developed villousities (minute projections) and conjunctive filaments distributed along medial line of posterior wall of stomach (Figs. 15, 19; sv), connecting this gastric wall to neighboring structures, mainly with adjacent visceral wall. Inner gastric surface (Fig. 19) mostly smooth (no clear sorting area visible), with thin, transparent gastric shield occupying ca. one quarter of surface, covering most of left-dorsal side, with anterior expansions to dorsal hood and to left duct to digestive diverticula; transverse fold wide and relatively tall, lying ventral to oesophageal apertures, with both ends diminishing; aperture to digestive diverticula a relatively wide single pair, located lateral to area ventral of transverse fold; left duct to digestive diverticula protected externally by expansion of transverse fold; another gastric fold narrow, extending obliquely from anteroventral edge of left duct to digestive diverticula, surrounding anterior edge of gastric shield, connecting with anterior branch of fold separating intestine and style sac; transition between gastric chamber and style sac-intestine marked by transverse, narrow fold almost completely surrounding orifice of style sac, except for a portion relative to intestinal origin where ends of transverse fold become broader, along short portion, abruptly curving perpendicularly to its preceding portion, running along style sac as pair of parallel folds separating style sac from intestine; this pair of longitudinal folds placed along right surface. Digestive diverticula as described above. Style sac straight, situated dorsoventrally, gradually narrowing to ventral end of visceral sac (Figs. 15, 19); style (Fig. 6) well developed, protruding inside gastric chamber, occupying



Figs. 18–22. *Semele sinensis* anatomy: 18, Pericardial structures, right view, with some adjacent organs also shown; 19, stomach, right view, sectioned longitudinally to expose inner surface; 20, cerebral ganglia, right and slightly anterior view; 21, pedal ganglia, right and slightly dorsal view, with border of visceral mass shown. au, auricle; co, cerebriovisceral connective; dd, ducts to digestive diverticula; dh, dorsal hood; es, oesophagus; fm, posterior foot retractor muscle; ga, genital aperture; gf, gastric fold; gs, gastric shield; in, intestine; ki, kidney; ne, nephropore; pc, pericardium; sd, stomach diverticulum; sf, fold separating intestine from style sac; ss, style sac; sv, stomach microvillousities; um, umbonal region; ve, ventricle; vg, visceral ganglia. Scale bars = 2 mm.

half of volume of chamber. Intestine narrow, becoming free from style sac subterminally, at distance from distal end equivalent to one-fiftieth of total length of style sac, at right side; thereafter extending sinuously to mid-level of style sac where it undergoes several short loops (eight or nine loops as in Fig. 15) along a distance equivalent to one-third of style sac length; after tightly coiled portion, extending dorsally a distance equivalent to one-quarter of style sac length to anterior end of pericardium; twisting posteriorly, passing through entire pericardium; estimated intestinal length ca. three times that of style sac. Anus simple, sessile, on ventral surface of posterior adductor muscle, in base of excurrent siphonal chamber.

Genital system (Fig. 18): Gonad as described above. Pair of short genital ducts receiving branches from several gonadal acini lying along posterior region of visceral sac. Genital pore (ga) simple, located a short distance from nephropore, slightly anterior and ventral to latter.

Central nervous system (Fig. 15): Pair of cerebral ganglia (Fig. 20) of ca. half the size of transverse section of oesophagus; each ganglion located very laterally, between protractor muscle of foot and posterodorsal end of anterior adductor muscle, protected by thin layer of pallial membrane; cerebral commissure long, almost as long as adductor muscle width. Pair of pedal ganglia (Fig. 21) fused with one another along median surface, located ca. midway between cerebral ganglia and ventral end of visceral cavity, contacting anterior wall of cavity (anterior retractor muscles of foot); volume of each pedal ganglion ca. equal to that of cerebral ganglion. Cerebropedal connective very narrow, extending through anterior foot retractor musculature. Visceral ganglia close to one another, at some distance (ca. one tenth of valve length) anterior to mid-region of posterior adductor muscle anterior surface (Fig. 18); volume of each visceral ganglion ca. equal to that of cerebral ganglion; each ganglion anteroposteriorly elongated (Fig. 22), with a pair of large posterior nerves, trifurcating after a distance equivalent to ganglion length; each ganglion also with pair of spherical dorsal protuberances, each ca. one sixth of gangliar volume; with one protuberance on mid-dorsal surface, other on posterior end of dorsal surface. Cerebrovisceral connective long, of twice the thickness of cerebropedal connective.

**Measurements.** – MZSP 62352 (#1): 32.5 × 33.3 × 17.8 mm.

**Distribution.** – Australia to Red Sea.

**Habitat.** – Muddy bottoms, from shallow water to 20 m depth; burrowing ca. 5 cm depth in sediment.

*Semele carnicolor* (Hanley, 1845)  
(Figs. 7–10, 23–34)

*Amphidesma carnicolor* Hanley, 1845: 162; Reeve, 1853, Pl. 1, Fig. 6.

*Semele carnicolor*: Kira, 1965: 169, Pl. 59, Fig. 17; Nielsen, 1976: 6, Fig. 70; Bosch et al., 1995: 261, Fig. 1169; Robba et al., 2002: 101, Pl. 15, Fig. 4.

For additional synonymy, see Robba et al., 2002: 101.

**Material examined.** – All Thailand, Chantaburi (Gulf of Thailand), Kungkrabaen Bay; 2 ex. (MZSP 55609), sta. KKB-04, mangrove hammock, 12°35.31'N 101°54.29'E, coll. Taylor & Glover, Aug.2005; 1 valve (MZSP 55306), sta. KKB-12, Hin Chao Lao Nai, 12°32.261'N 101°55.472'E, snorkeling, coll. Simone, Aug.2005.

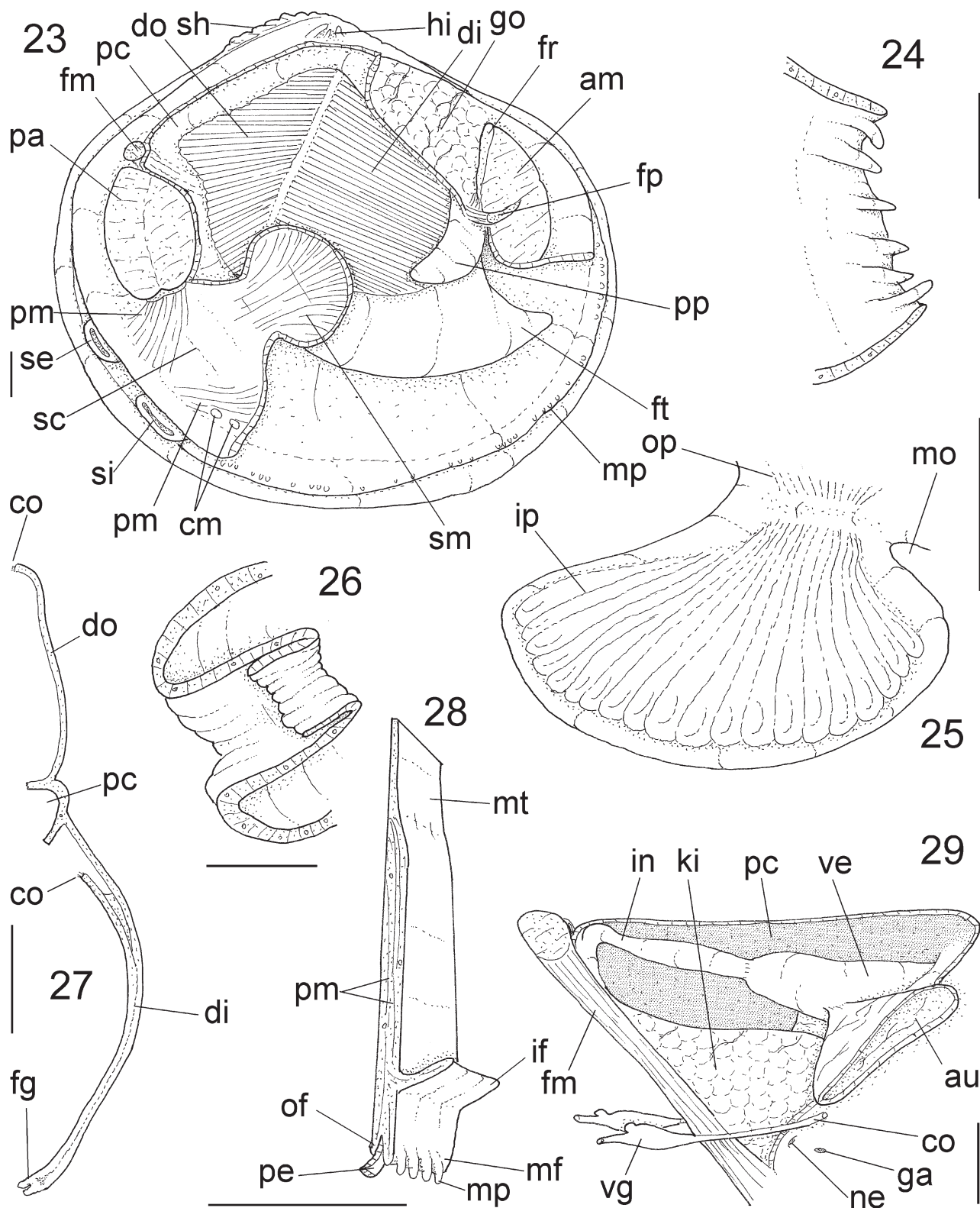
**Description.** – Shell (Figs. 7–10): Outline somewhat circular (dorsoventral height ca. 85% of anteroposterior length); laterally flattened (width ca. 40% of length); walls relatively thick. Colour pale brown to beige, with irregular dark brown spots randomly distributed in some specimens (Figs. 7, 9). Sculpture uniformly commarginal, with relatively tall scale-like lamellae (Figs. 7, 10), ca. one per mm; each scale separated from neighboring scales by space equivalent to seven to eight times its width. Very delicate radial furrows detectable in interspaces between scales, of width equivalent to that of commarginal sculpture, ca. six per mm; radial sculpture also detectable on both sides of scales, producing micro-undulations. Inner surface whitish, glossy (Fig. 8). Hinge very similar to preceding species, except in being more horizontal and by having slightly shorter anterior lateral tooth on right valve (Fig. 8).

Main muscle system (Figs. 23, 30): Posterior adductor muscle slightly larger, approximately equal in size to anterior adductor muscle; dorsal end somewhat bluntly pointed. Pair of pedal protractor muscles penetrating nearly entire adductor muscle width at their origin. Pair of anterior pedal retractor muscles originating narrowly, in area ca. one-twentieth of that of anterior adductor muscle. Pair of posterior pedal retractor muscles originating in rounded area equivalent to one fiftieth of that of adductor muscle. Cruciform muscle of total length ca. 40% of width of posterior adductor muscle (Fig. 23; cm).

Mantle (Figs. 23, 28): Middle fold papillae separated by distance equivalent to twice their width (Fig. 28). Tip of incurrent siphon bearing six papillae (Fig. 24), each with pointed tip, separated from next by distance equivalent to four times papillar width; smooth between papillae. Excurrent siphon retracted not only by contraction of walls, but also by three successive interior folds (Fig. 26). Dorsal elements of retractor muscles of lateral walls of siphonal chamber with origins more ventrally positioned, restricted to ventral end of posterior adductor muscle (area equivalent to one-thirtieth of adductor muscle). Pair of ventral elements of lateral walls of siphonal chamber originating along pallial line (Fig. 23; pm).

Pallial cavity (Fig. 23): Labial palps somewhat rounded (Fig. 23; pp); each hemipalp of ca. one twenty-fifth of valve area. Inner palp surface (Fig. 25) possessing folds disposed divergently; smooth (lacking folds) area surrounding each entire hemipalp edge, this area mostly equivalent to half fold of palp (at its ventral end); smooth area becoming weakly wider in dorsal region of each side. With ca. 20 to 25 folds





Figs. 23–29. *Semele carnicolor* anatomy: 23, Whole right view, with right valve and part of right mantle lobe removed; 24, incurrent siphon, inner view, detail of tip opened longitudinally; 25, inner hemipalp and some adjacent structures, right view; 26, contracted excurrent siphon, inner view, opened longitudinally; 27, gill, transverse section at mid-region; 28, mantle edge, transverse section of ventral portion at mid-region; 29, pericardial structures, right view, with some adjacent organs also shown. am, anterior adductor muscle; au, auricle; cm, cruciform muscle; co, cerebrovisceral connective; di, inner demibranch; do, outer demibranch; fg, gill food groove; fm, posterior foot retractor muscle; fp, foot protractor muscle; fr, anterior foot retractor muscle; ft, foot; ga, genital aperture; go, gonad; hi, hinge; if, inner fold of mantle border; in, intestine; ip, inner hemipalp; ki, kidney; mf, middle fold of mantle border; mo, mouth; mp, mantle papillae; mt, mantle; ne, nephropore; of, outer fold of mantle border; op, outer hemipalp; pa, posterior adductor muscle; pc, pericardium; pe, periostracum; pm, pallial muscles; pp, labial palp; se, excurrent siphon; sh, shell; si, incurrent siphon; sm, siphonal retractor muscle; ve, ventricle; vg, visceral ganglia. Scale bars = 1 mm.

on each hemipalp; each fold narrow at dorsal end, appearing gradually after smooth furrow positioned between hemipalps, gradually becoming wider towards ventral; ventral end five to six times wider and taller than dorsal end; ventral region of each fold as tall as septum, with rounded end. Posterior folds of palps longer and more horizontally positioned than anterior folds (Fig. 25). Palp ca. two times longer than wide. Gills (Fig. 23) more vertically positioned than preceding species. Inner demibranch lacking septum between descending and ascending branches of its filaments (Fig. 27).

Visceral mass (Fig. 30): Visceral sac longer anteroposteriorly than in preceding species (length ca. two thirds of height).

Circulatory and excretory systems (Figs 29–30): Auricle slightly smaller (ca. half of pericardial length) and positioned more anteriorly turned than in *Semele carnicolor*. Kidney white. Nephropore a simple oval orifice on mid-region of wall between kidney and pallial cavity (Fig. 29; ne).

Digestive system (Fig. 30): Stomach ducts to digestive diverticula turned ventrally ca. one-fiftieth of stomach size, narrow and less branched than in preceding species. Gastric diverticulum extending directly posterodorsally, along a distance equivalent to entire stomach length; inner surface smooth (Figs. 30–31). Dorsal hood (dh) of ca. one tenth of length and half width of gastric diverticulum volume. Villosities and conjunctive filaments not evident. Inner gastric surface (Fig. 31) mostly smooth (no clear sorting area visible), with anterior expansions to dorsal hood and to left duct to digestive diverticula. Transverse fold wide, relatively tall, lying ventral to oesophageal aperture, with both ends diminishing; aperture to digestive diverticula a relatively narrow single pair on sides of area ventral to transverse fold and partially covered dorsally by it; no other visible gastric folds; transition between gastric chamber and style sac-intestine marked by transverse, broad, tall fold surrounding orifice of style sac almost completely, except for a portion relative to intestinal origin (Fig. 31; sf). Style sac straight, situated dorsoventrally, narrowing gradually to ventral end of visceral sac, of length ca. half of visceral sac. Intestine narrow, becoming free from style sac terminally; thereafter extending almost straight to mid-level of style sac, at this level performing several short loops (five or six loops as in Fig. 30) along a distance equivalent to half of style sac length; estimated intestinal length ca. three times that of style sac. Anus on posteroventral surface of posterior adductor muscle.

Genital system: Gonad as described above. Genital pore (Fig. 29; ga) simple, located at short distance from nephropore, slightly anterior and ventral to latter.

Central nervous system (Fig. 30): Cerebral ganglia (Fig. 33) ca. half size of cross section of oesophagus; cerebral commissure long, almost as long as adductor muscle width. Pair of pedal ganglia (Fig. 32) fused with each other along median surface, located approximately between middle and ventral thirds of distance between cerebral ganglia and ventral end of visceral cavity; volume of each pedal

ganglion ca. one-half of cerebral ganglion. Visceral ganglia close to each other, at some distance (ca. one-tenth of valve length) anterior to mid-region of posterior adductor muscle anterior surface; volume of each visceral ganglion (Fig. 34) ca. equal to that of cerebral ganglion; each ganglion with single spherical posterodorsal protuberance, of ca. one-sixth of gangliar volume.

**Measurements.** – MZSP 55309 (#1): 12.7 × 14.2 × 5.0 mm.

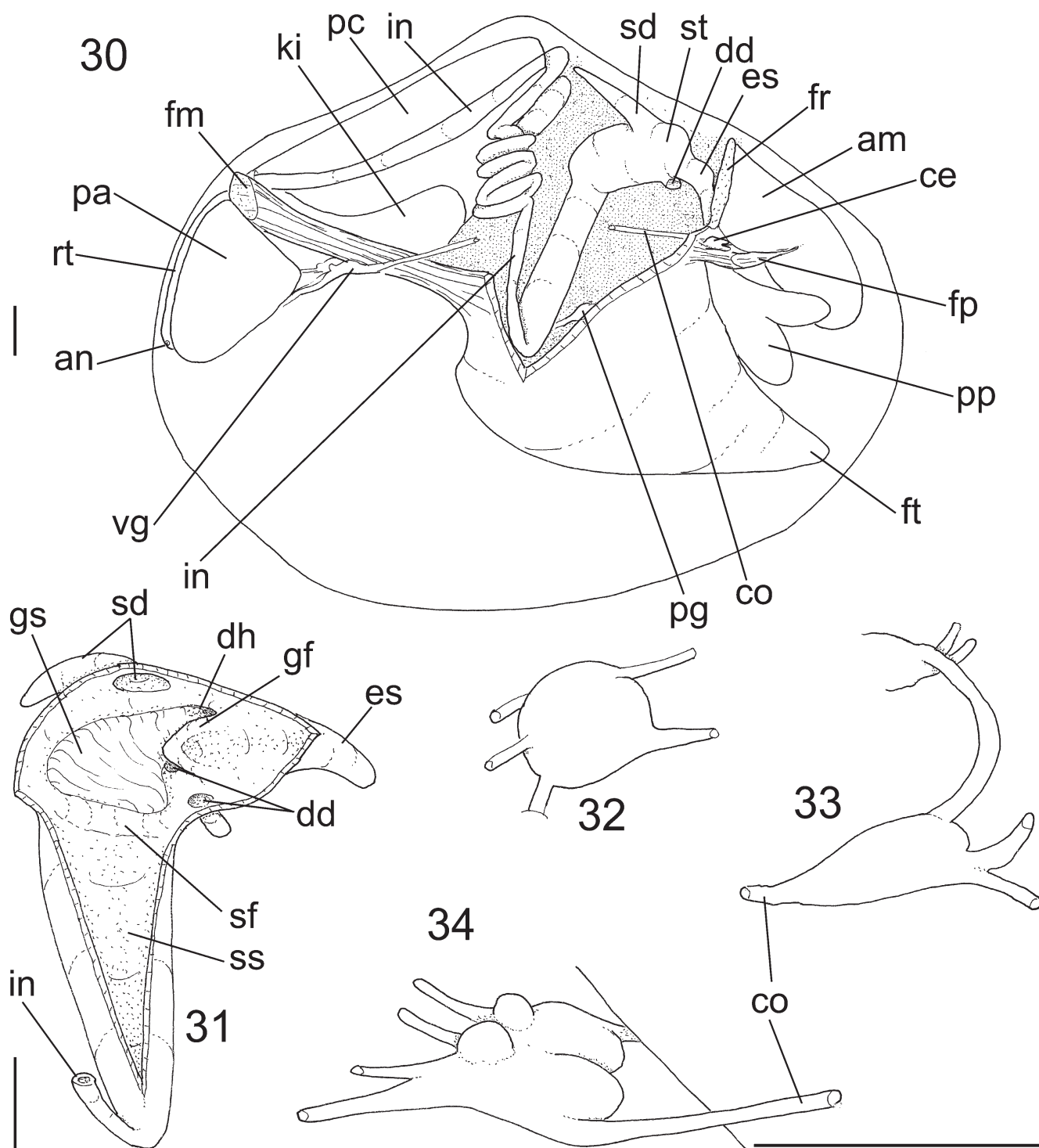
**Distribution.** – Japan to Red Sea.

**Habitat.** – Sand-mud bottoms, from shallow water to 25 m depth; burrowing ca. two to three centimetres below sediment surface.

## DISCUSSION

*Semele sinensis* and *S. carnicolor* appear to be the more common species of semelids in the Gulf of Thailand. They occur in similar habitats, although *S. carnicolor* apparently is found in more sandy sediment. The conchology and also the anatomy show important distinctions between the two species, as explored in the above descriptions. Shell sculpture is apparently the easiest character to distinguish the species; *S. sinensis* has a delicate net of commarginal and radial sculpture, equally developed, whereas *S. carnicolor* has much stronger commarginal sculpture, with tall scales well-separated from each other and with delicate undulations.

Anatomically, each species has several differences (see Description of *S. carnicolor*). The main differences are in the labial palps, which are proportionally larger in *S. sinensis*, with a completely different arrangement of inner folds. The inner palp folds in *S. sinensis* are very narrow, located very close to each other, producing a somewhat uniform surface, whereas in *S. carnicolor* the inner palp folds are much fewer and proportionally wider and taller, mainly at the ventral end; the inner folds are almost invariably perpendicularly situated in *S. sinensis*, whereas they are radially disposed in *S. carnicolor*; the smooth portion of the palp inner surface, i.e., the portion lacking folds, is proportionally wider in *S. sinensis*, mainly in the dorsal region (Fig. 17), than in *S. carnicolor* (Fig. 25). Another distinction is in the separation of the intestine from the style sac; the separation point is subterminal in *S. sinensis* (Fig. 15), whereas it is terminal in *S. carnicolor* (Fig. 30). The proportional length of the gastric diverticulum, at the posterodorsal-right region of the stomach, is much shorter and curved in *S. sinensis* (Fig. 15; sd), and longer and straight in *S. carnicolor* (Fig. 30). The posterior surface of the stomach has clear villosities and ligaments in *S. sinensis* (Figs. 15, 19; sv); these are not developed in *S. carnicolor* (Figs. 30–31). Beyond the digestive system, other structures also show distinctive features, such as the tip of the incurrent siphon; despite the fact that they both bear six papillae, *S. sinensis* possesses secondary papillae among the main papillae (Fig. 16), whereas this region is smooth in *S. carnicolor* (Fig. 24). The visceral ganglia have



Figs. 30–34. *Semele carnicolor* anatomy: 30, Visceral structures as in situ, right view, with topology of some adjacent structures also shown; 31, stomach, right view, sectioned longitudinally to expose inner surface; 32, pedal ganglia, right and slightly posterior view; 33, cerebral ganglia, right and slightly dorsal view; 34, visceral ganglia, right and slightly dorsal view, with border of visceral mass shown. am, anterior adductor muscle; an, anus; ce, cerebral ganglia; co, cerebrovisceral connective; dd, ducts to digestive diverticula; dh, dorsal hood; es, oesophagus; fm, posterior foot retractor muscle; fp, foot protractor muscle; fr, anterior foot retractor muscle; ft, foot; gf, gastric fold; gs, gastric shield; in, intestine; ki, kidney; pa, posterior adductor muscle; pc, pericardium; pg, pedal ganglia; pp, labial palp; rt, rectum; sd, stomach diverticulum; sf, fold separating intestine from style sac; ss, style sac; st, stomach; vg, visceral ganglia. Scale bars = 1 mm.

two pairs of dorsal protuberances in *S. sinensis* (Fig. 22), and a single pair in *S. carnicolor* (Fig. 34).

Although other anatomical studies on semelids are found in the literature, these rarely bear the details necessary for a complete comparison. The most complete knowledge exists for *Semele purpurascens* (Gmelin, 1791) and *S. proficua* (Pulteney, 1799) provided by Boss (1972), Narchi & Domaneschi (1977), and Domaneschi (1982, 1995). It is possible to note that both Thai species differ from these western Atlantic species by the arrangement of palp inner folds, by less intense intestinal coiling, by less developed gastric caeca, and by the absence of the paired pedal elevator muscles. Both western Atlantic species apparently possess papillae on the excurrent siphon (Boss, 1972; Domaneschi, 1995: figs. 2–3), which are absent in the Thai species. Beyond these differences, all *Semele* species with known anatomy are similar, mainly in musculature (e.g., Schröder, 1916; Graham, 1934) and gill structure (Kellogg, 1915; Atkins, 1937; Yonge, 1949; Domaneschi, 1995), which are mostly typically tellinoidean.

Beyond the well-known internal element of the ligament that defines the family (e.g., Trueman, 1953; Boss, 1972), other anatomical characters could prove to be additional synapomorphies of Semelidae, such as the long gastric diverticulum placed on the right side, the intense coiling of the intestine in its middle region, the medial fusion of the pedal ganglia, and the protuberances on the visceral ganglia.

#### ACKNOWLEDGMENTS

The International Marine Bivalve Workshop (with contributions on other molluscan groups) in Chantaburi, Thailand, was organised by Kashane Chalermwat (Burapha University), Fred Wells (Western Australian Department of Fisheries), Rüdiger Bieler (Field Museum of Natural History, Chicago) and Paula M. Mikkelsen (American Museum of Natural History), and supported by U. S. National Science Foundation grant PEET DEB-9978119 (to RB and PMM). Field transportation in Thailand and chemicals were provided by the Faculty of Science, Burapha University. This study was partially developed under the governmental support of Fapesp (Fundação de Amparo à Pesquisa do Estado de São Paulo) process 2004/02333-8.

#### THAI ABSTRACT

งานวิจัยฉบับนี้นำเสนอกายวิภาคเปรียบเทียบของหอยสองฝากลุ่มซีมีลิคจากประเทศไทยสองชนิดจากการเก็บตัวอย่างบริเวณอ่าวทุ่งกระเบน คือ *Semele sinensis* A. Adams, 1853 และ *S. carnicolor* (Hanley, 1845) ที่มีการแพร่กระจายทั่วภาคพื้นอินโด-แปซิฟิก รูปร่างลักษณะของหอยทั้งสองชนิดเป็นแบบหอยเทลลินอยเคียทั่วไป โดยเฉพาะเอ็นบานพับเปลือกที่มีลักษณะยาวและฝังอยู่ภายในระหว่างเปลือก และการมีช่องว่างระหว่างเนื้อเยื่อ

แมนเทิลพับในสุดกับพับนอกที่เหลืออีกสองพับ นอกจากนั้น ท่อนำอาหารเข้าสู่ต่อมย่อยอาหารที่มีลักษณะยาวและมีการแตกแขนงรวมทั้งมีถุงทางเดินอาหารแยกจากกระเพาะบริเวณด้านบน ส่วนท้ายของกระเพาะทอดยาวออกไปทางด้านหลัง ความแตกต่างที่เด่นชัดที่สุดของหอยทั้งสองชนิดในรายงานนี้อยู่ที่ลักษณะรูปร่างของเลบิเยลแพลป์ (labial palp)

#### LITERATURE CITED

- Adams, A., 1853. Descriptions of new species of *Semele*, *Rhizochilus*, *Plotia* and *Tiara* in the Cumingian collection. *Proceedings of the Zoological Society of London*, **21**: 94–99.
- Atkins, D., 1937. On the ciliary mechanisms and interrelationships of lamellibranches. Part 3. *Quarterly Journal of Microscopical Science*, **79**: 375–421.
- Bosch, D.T., S. P. Dance, R. G. Moolenbeek & P. G. Oliver, 1995. *Seashells of Eastern Arabia*. Motivate Publishing, Dubai. 296 pp.
- Boss, K.J., 1972. The genus *Semele* in the western Atlantic (Semelidae; Bivalvia). *Johnsonia*, **5**(49): 1–32.
- Boss, K. J., 1982. Mollusca. In: Parker, S. P. (ed.), *Synopsis and Classification of Living Organisms, Volume 1*. McGraw-Hill, New York. Pp. 945–1166.
- Domaneschi, O., 1982. Anatomia funcional de *Semele proficua* (Pulteney, 1799) (Bivalvia: Semelidae). In: Salinas, P. J. (ed.), *Zoologia Neotropical. Actas del VIII Congreso Latinoamericano de Zoología, Mérida, Venezuela*, **1**: 387–436.
- Domaneschi, O., 1995. A comparative study of the functional morphology of *Semele purpurascens* (Gmelin, 1791) and *Semele proficua* (Pulteney, 1799) (Bivalvia: Semelidae). *The Veliger*, **38**(4): 323–324.
- Fischer, P. H., 1857. Observations anatomiques sur des mollusques peu connus. *Journal de Conchyliologie*, **6**(4): 327–339, pl. 8.
- Gmelin, J. F., 1791. *Caroli a Linné ... Systema Naturae per Regna Tria Naturae, Secundum Classes, Ordines, Genera, Species, cum Characteribus, Differentiis, Synonymis, Locis . . . Editio decima tertia, aucta, reformata. Volume 1, Part 6*. G. E. Beer, Lipsiae [Leipzig]. Pp. 3021–4120.
- Graham, A., 1934. The structure and relationships of lamellibranches possessing a cruciform muscle. *Proceedings of the Royal Society of Edinburgh*, **54**: 158–187.
- Hanley, S., 1845 (“1844”). Descriptions of new species of *Cyrena*, *Venus* and *Amphidesma*. *Proceedings of the Zoological Society of London*, **12**(140): 159–162.
- Kellogg, J. L., 1915. Ciliary mechanisms of lamellibranches with descriptions of anatomy. *Journal of Morphology*, **26**: 625–701.
- Kira, T., 1965. *Shells of the Western Pacific in Color, Volume 2*. Hoikusha Publishing, Osaka, Japan. 224 pp.
- Lamy, É., 1914. Revision des Scrobiculariidae vivants du Muéum d’Histoire Naturelle de Paris. *Journal de Conchyliologie*, **61**(3): 243–268, pl. 8.
- Narchi, W. & O. Domaneschi, 1977. *Semele casali* Doello-Jurado, 1949 (Mollusca-Bivalvia) in the Brazilian littoral. *Studies on Neotropical Fauna and Environment*, **12**(4): 263–272.
- Nielsen, C., 1976. An illustrated checklist of bivalves from PMBC beach with a reef-flat at Phuket, Thailand. *Phuket Marine Biology Research Bulletin*, **9**: 1–7.

- Pulteney, R., 1799. *Catalogues of the Birds, Shells and Some of the More Rare Plants, of Dorsetshire*. J. Nichols, London. [i] + 92 pp.
- Reeve, L. A., 1853. Monograph of the genus *Amphidesma*. *Conchologica Iconica; or, Illustrations of the Shells of Molluscous Animals*, **8**: 7 pls.
- Robba, E., I. D. Geronimo, N. Chaimanee, M. P. Negri & R. Sanfilippo, 2002. Holocene and Recent shallow soft-bottom mollusks from the northern Gulf of Thailand area: Bivalvia. *Bollettino Malacologico*, **38**(5–8): 49–132.
- Schröder, O., 1916. Beiträge zur Anatomie von *Amphidesma solium*. *Jenaische Zeitschrift für Naturwissenschaft*, **54**: 101–132.
- Schumacher, C. F., 1817. *Essai d'un Nouveau Système des Habitations des Vers Testacés*. Schultz, Copenhagen. 287 pp., 22 pls.
- Trueman, E. R., 1953. The structure of the ligament of the Semelidae. *Proceedings of the Malacological Society of London*, **30**(1–2): 30–36.
- Yonge, C. M., 1949. On the structure and adaptations of the Tellinacea, deposit-feeding Eulamellibranchia. *Philosophical Transactions of the Royal Society of London (B)*, **234**(609): 29–76.