



## Anatomical description of *Ziba carinata* from Ghana (Caenogastropoda, Mitridae)

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### Abstract

The anatomy of the mitrid *Ziba carinata*, type species of the genus, is described based on a sample from Ghana, W. Africa. The species is characterized by very wide radular lateral teeth; a very short odontophore horizontal muscle; a strong, bifurcated, a dorsal muscle from radular sac to dorsal region of odontophore (m9); a pair of auxiliary retractor muscles for the radula (m2a); a very developed epiproboscis lacking an internal duct; the lack of accessory salivary glands; ducts of the salivary glands long and convolute; stomach with a circular, sphincter-like anterior muscle; and a very concentrated nerve ring with pair of statocysts located relatively away from it. The radular teeth are very wide and with long cusps. This description allows future reevaluation of the genus and an analysis of its separation from closely related genera.

Key words: *Ziba carinata*; type species; Ghana; anatomy; taxonomy.

### Resumo

A anatomia do mitrídeo *Ziba carinata*, espécie tipo do gênero, é descrita baseada em uma amostra de Gana, W. África. A espécie é caracterizada pelo dente radular lateral muito largo; músculo horizontal do odontóforo muito curto; um músculo dorsal, bifurcado e forte do saco radular até a região dorsal do odontóforo (m9). Par de músculos retratores auxiliares da rádula (m2a); epiprobóscide muito desenvolvida, carecendo de ductos internos; ausência de glândulas salivares acessórias; ductos das glândulas salivares longas e convolutas; estômago com um músculo anterior circular, como um esfíncter; e um anel nervoso muito concentrado, com estatocistos localizados afastados desse. Os dentes radulares são muito largos e com cúspides alongadas. Esta descrição permite uma futura reavaliação do gênero e uma análise de sua separação dos gêneros mais próximos.

Palavras-chave: *Ziba carinata*; espécie-tipo; Gana; anatomia; taxonomia.

### Introduction

*Ziba carinata* (Swainson, 1824) is the type species of the genus *Ziba* H. & A. Adams, 1853 (SD of Wenz, 1938). The species was described in the genus *Mitra* Lamarck, 1798, with the type locality Sierra Leone, West Africa. Beyond this species, about two dozen other species have been referred to this genus worldwide. However, a strong taxonomical definition of the genus is still necessary, as its set of characters are sometimes found in representatives of other mitrid genera (Thorsson & Salisbury, 2008). Part of the problem is the lack of a detailed anatomical study of the type species, a gap that this paper addresses. The conchological definition of *Ziba*, as well as some information on the taxonomy and history

of this taxon, can be found elsewhere (e.g., Cernohorsky, 1991; Thorsson & Salisbury, 2008). This study is part of a project related to revisions of mitriform neogastropods, one of which has already been published (Turner & Simone, 1998). The senior author of the present study is responsible for the anatomical investigation, while the junior author works on the taxonomy and conchology. Unfortunately, the junior author passed away before the conclusion of this study. As the present paper is one of the series which was almost done, and it is related to an important feature of the Mitridae taxonomy, the senior author decided to complete the work and publish it.

## Material and Methods

A list of examined specimens follows the species description. The shells were broken, the soft parts extracted and dissected by standard techniques, under a stereomicroscope, with the specimens immersed in 70% ethanol. Shell details and radula were also examined with a Scanning Electronic Microscope (SEM), in the Museu de Zoologia da Universidade de São Paulo (MZSP), using standard techniques.

Abbreviations used in anatomical drawings: **aa**, anterior aorta; **af**, afferent gill vessel; **ag**, albumen gland; **an**, anus; **au**, auricle; **ba**, bursa copulatrix aperture; **bc**, bursa copulatrix; **bg**, buccal ganglion; **br**, subradular membrane; **bv**, blood vessel; **ca**, capsule gland/vestibule aperture; **ce**, cerebral ganglion; **cg**, capsule gland; **cm**, columellar muscle; **cv**, ctenidial vein; **dd**, duct to digestive gland; **di**, diaphragm-like septum, separating haemocoel from visceral cavity; **ea**, aperture of epiproboscis into oral tube; **ei**, epiproboscis inner projection; **em**, epiproboscis middle muscle; **ep**, epiproboscis; **es**, esophagus; **ey**, eye; **fg**, female gland of foot sole; **fp**, female pore; **fs**, foot sole; **ft**, foot; **gi**, gill; **gm**, gastric muscle; **gp**, pedal ganglion; **he**, head; **hg**, hypobranchial gland; **ig**, ingesting gland; **in**, intestine; **km**, membrane between kidney and pallial cavity; **kv**, kidney ventral lobe; **mb**, mantle border; **mc**, peri-buccal or oral tube circular muscle fibers; **md**, longitudinal muscle of proximal end of epiproboscis; **me**, muscle of distal end of epiproboscis; **mj**, muscle of oral tube walls; **mo**, mouth; **mt**, dilator muscles of oral tube and mouth; **ne**, nephrostome; **ng**, nephridial gland; **nr**, nerve ring; **nv**, nerve; **oc**, odontophore cartilage; **of**, odontophore; **os**, osphradium; **ot**, oral tube; **ov**, pallial oviduct; **pb**, proboscis; **pg**, pedal gland furrow; **po**, projection of buccal mass bulging inside oral tube; **py**, pallial cavity; **ra**, radula; **rc**, rhynchodeal cavity; **rm**, retractor muscle of proboscis; **rn**, radular nucleus; **rs**, radular sac; **rw**, rhynchodeal wall; **ry**, rhynchostome; **sa**, salivary gland aperture; **sc**, subradular cartilage; **sd**, salivary duct; **sg**, salivary gland; **si**, siphon; **sp**, sphincter of rhynchostome; **sr**, supra-esophageal ganglion; **st**, stomach; **su**, sub-esophageal ganglion; **sy**, statocyst; **te**, tentacle; **tg**, integument; **ve**, ventricle; **vt**, vestibule of pallial oviduct.

## Systematics

**Order: Neogastropoda**  
Family Mitridae

Genus *Ziba* H. & A. Adams, 1853

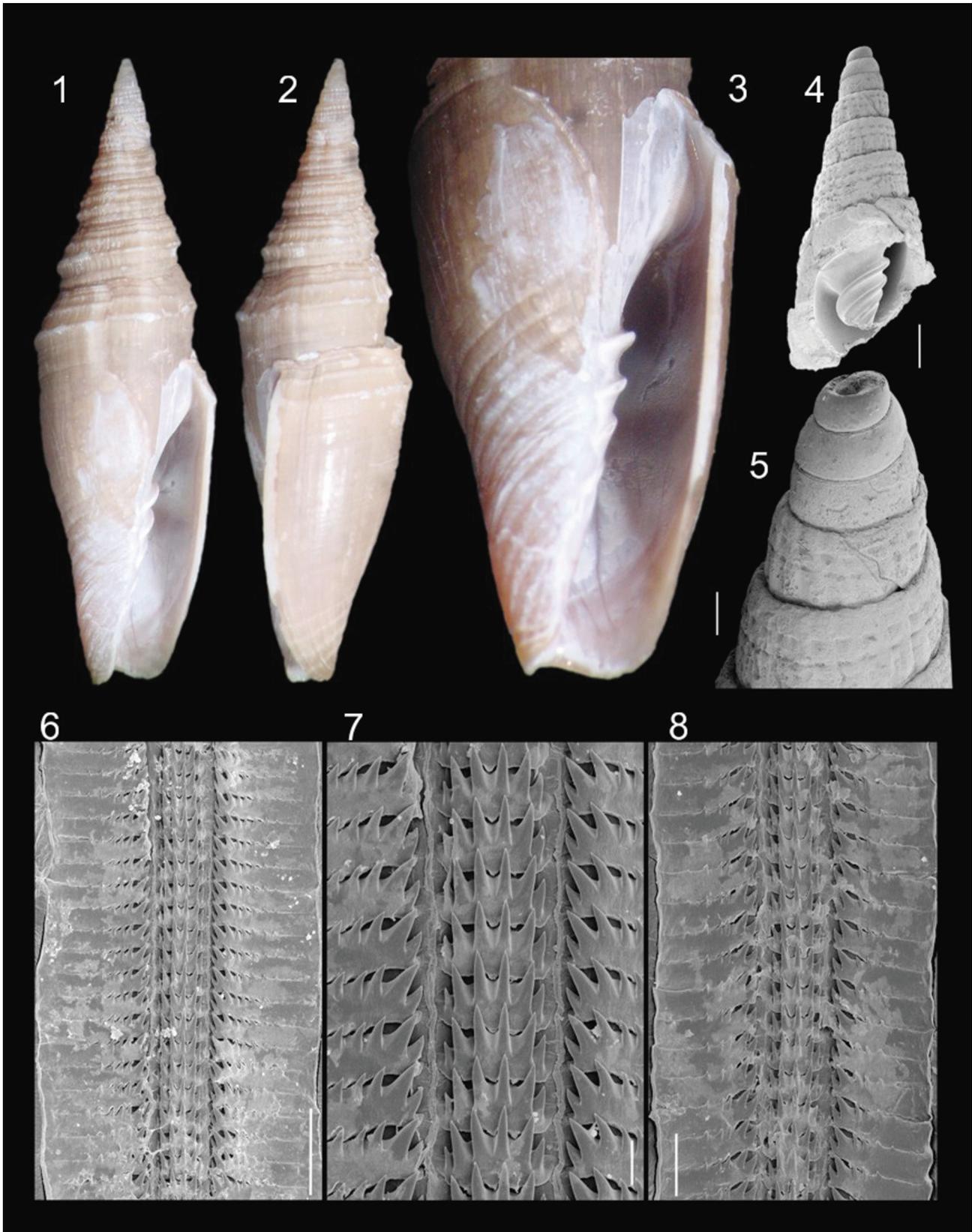
***Ziba carinata*** (Swainson, 1824)  
(Figs. 1-26)

- Mitra carinata* Swainson, 1824 (pl. 2, fig. 3); Bernard, 1984: 91 (fig. 164).  
*Mitra senegalensis* Reeve, 1844: 17 (fig. 129), 1845: 485; Heinicke, 1980: 5 (fig. B).  
*Turricula (Ziba) carinata*: Adams & Adams, 1853: 179.  
*Turricula (Ziba) senegalensis*: Adams & Adams, 1853: 179.  
*Mitraria (Ziba) carinata*: Wenz, 1938: 1292 (fig. 3682).  
*Ziba carinata*: Cernohorsky, 1970: 47; 1980: 8; Rehder & Wilson, 1975: 13; Heinicke, 1980: 5 (fig. A); Salisbury, 1991: 48-50; Ardevini & Cossignani, 2004: 200 (fig.); Thorsson & Salisbuty, 2008: 3.  
*Mitra (Ziba) carinata*: Burnay & Monteiro, 1978: 1.  
*Cancilla carinata*: Abbott & Dance, 2000: 203 (fig.).

## Description

**Shell** (Figs. 1, 5). About 3 times longer than wide. Spire almost half of total length. Protoconch of 2 smooth, weakly convex whorls (Figs. 4, 5). Border protoconch-teleoconch unclear. Sculpture of first whorls a regular reticulate (Figs. 4, 5), with 3-4 spiral cords; this sculpture gradually disappearing after 4-5 whorls. Sculpture normally 3-4 subsutural, spiral cords, with inferior cord somewhat larger, forming low shoulder or carina; this can be absent in some specimens. Aperture ~ 2.3 times smaller than length (Figs. 1, 2). Inner lip possessing 4 central folds, gradually increasing upwards; first inferior fold weak and more oblique (Fig. 3). Columella with 3 strong folds in middle level of each whorl (Fig. 4). Other details in Cernohorsky (1970, 1980).

**Head-foot** (Figs. 9, 13-16). Color pale beige. Form flat, antero-posteriorly long. Head protruded, socket-like, base flat and broad, about as wide as long (Figs. 9, 13). Tentacles stubby, basal half clearly broader than distal half, division marked by small ommatophore (Figs. 13, 15). Eyes small, situated in middle level of tentacles outer edge. Rhynchostome preceded by elongated, muscular region; its aperture slightly protruded between both tentacles (Figs. 13, 15: ry). Foot somewhat triangular (Fig. 14), of about half whorl; anterior edge mostly bearing pedal gland furrow and extending laterally little beyond remaining sole region. Columellar muscle with about 1 whorl, strongly furrowed by 3 longitudinal grooves, due to columellar folds (Fig. 9: cm). Haemocoel long and broad, slightly oblique (Fig. 13); occupying most of head-foot width. Operculum absent.



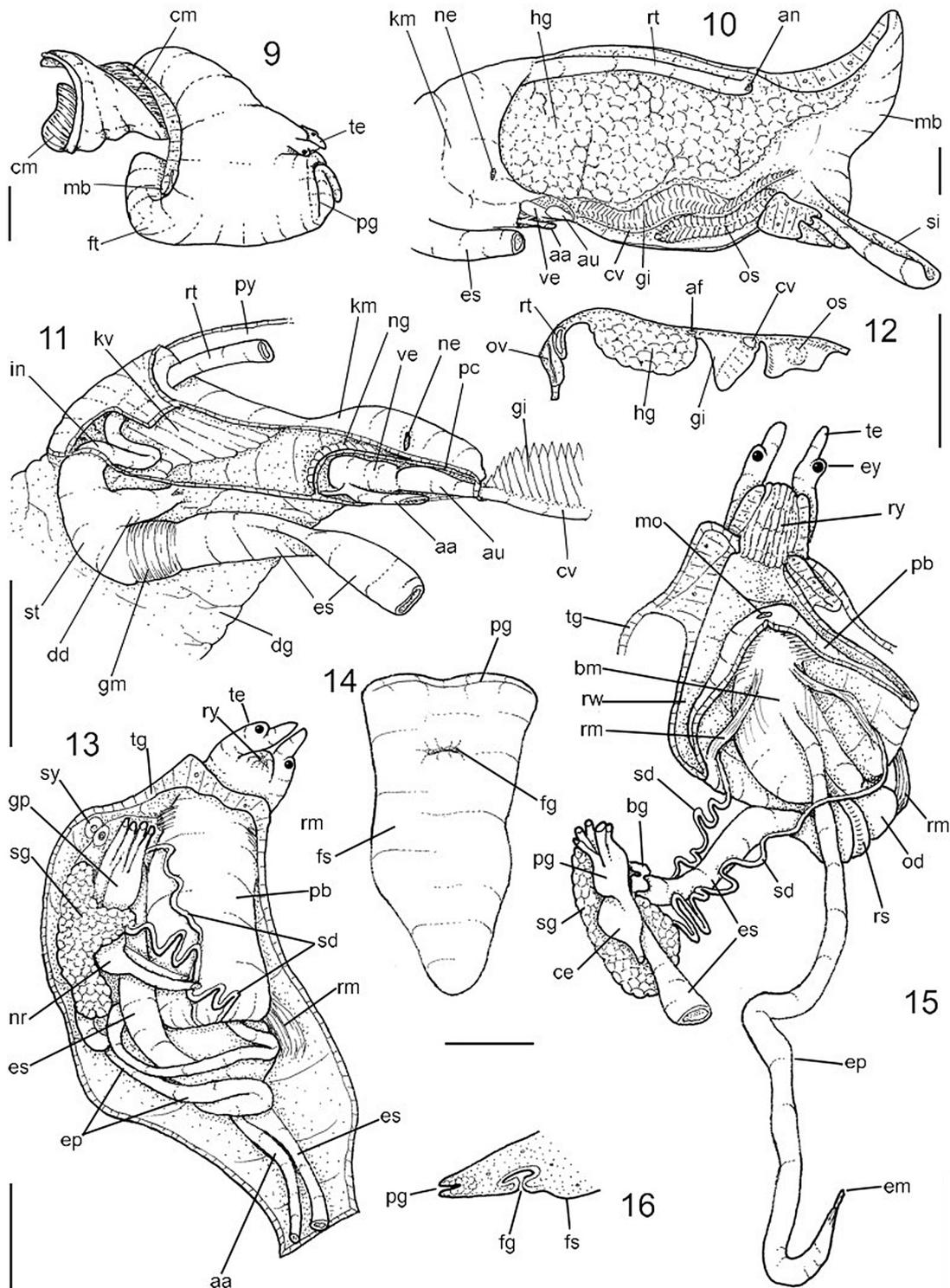
Figs 1-8 *Ziba carinata* shell and radulae in SEM: **1**, specimen MZSP 94071 (from Ghana), frontal view, length = 18.1 mm; **2**, same, right view. **3**, same, detail of aperture, frontal-slightly right view; **4**, spire and columellar folds, SEM, scale = 500  $\mu$ m; **5**, detail of protoconch and first teleoconch whorls, SEM, scale = 200  $\mu$ m; **6-8**, radulae (2 specimens); **6**, whole view, scale = 100  $\mu$ m; **7**, detail of central region, scale = 20  $\mu$ m; **8**, whole view (another specimen), scale = 50  $\mu$ m.

**Mantle organs** (Figs. 10-12). Pallial cavity with about 1.5 whorls. Mantle edge smooth, slightly thick. Siphon long and narrow, edges smooth; length about 1/3 of that of pallial cavity. Osphradium about 5 times longer than wide; situated just posterior to siphon base and along left edge of cavity. Osphradium filaments almost symmetrical, except for right-most filaments being slightly taller and with a broadly pointed tip (Fig. 12: os). Gill narrow, about 6 times narrower than cavity; about same length as cavity and about double of osphradium length; running close to cavity left edge; anterior end pointed, more anterior than that of osphradium. Gill filaments short, slightly broad, tip rounded; about as tall as wide. Between gill and rectum a very broad space, 4-5 times broader than gill area. Hypobranchial gland occupying most of this area, whitish, somewhat thick (Figs. 10, 12: hg). Rectum narrow, running along cavity right edge. Anus simple, situated before anterior 1/3 of cavity length. shells, 87487, 20 shells, 88190, 8 shells, MNRJ 12869, 2 shells, USNM, 2 shells.

**Circulatory and excretory systems** (Figs. 10, 11). Heart less than 1/4 of renal area, located just posterior to gill, about 3 times longer than wide; auricle anterior to ventricle. Aortas inserted in left surface of ventricle; anterior aorta about 4 times larger than posterior aorta. Kidney laterally broad, antero-posteriorly short (about 1/8 whorl), oblique, color pale-beige. Renal dorsal lobe flattened low, surface uniform, filling entire right half of renal dorsal surface, surrounding at some distance from pericardium, ending close to nephrostome. Renal ventral lobe short, partially connected to dorsal lobe along its right edge, and with about its half volume; surrounding anterior half of intestine crossing kidney. Nephrostome a small, transverse slit located in anterior region of membrane between kidney and pallial cavity.

**Digestive system** (Figs. 11, 13, 15, 17-25). **Proboscis** with about half of haemocoel volume and almost as long as foot when protruded. Rhynchostome preceded by somewhat long muscular tube, ~3 times longer than wide; inner surface with 8-10 longitudinal folds (Fig. 15: ry). Rhynchodeal wall weakly muscular, lateral regions almost a simple, translucent membrane, more developed muscular tissue close to median line (dorsal and ventral) (Figs. 13, 15: rw). Buccal portion of proboscis with about half of total proboscis length; walls thick muscular (Fig. 15). Proboscis retractor muscles sparse, narrow, about 6-8 pairs, most attached to entire proboscis inner surface (Figs. 13, 15: rm). **Buccal mass** somewhat large, occupying about half of proboscis volume. Oral tube occupying about half of buccal mass length,

composed by 2 walls (Figs. 20, 21): 1) a thin, semi-transparent, outer wall, inner surface smooth, outer surface entirely covered by small radial muscle fibers (Figs. 17, 18: **m1**) connecting it to adjacent inner surface of proboscis and buccal mass; 2) inner wall thick-muscular, protruding inside chamber formed by outer wall, most musculature circular (Fig. 17: **mc**); continuing towards odontophore, at border becoming abruptly thin. This inner wall of oral tube bearing 2 inner orifices (Fig. 20): 1) dorsally, esophagus origin, somewhat small, circular, surrounded in by broad and short longitudinal fold in each side, and some smaller folds between them (es); 2) ventral, of epiproboscis, preceding odontophore, small, long antero-posteriorly, with shallow, transverse furrow in its anterior edge (Fig. 20: ea). **Epiproboscis** about as long and as wide as esophagus; constituted by outer, thin wall and solid, cylindrical, inner structure; both with about same length (Fig. 19). Outer wall possessing 3 very thin layers: inner layer chitin-like, iridescent; intermediary layer of longitudinal muscle fibers; outer layer of circular muscle fibers. Two pair of muscles connecting anterior end of epiproboscis on ventral surface of oral tube (Fig. 19: md); a muscle pair close to median line, running forwards; other pair more lateral, running towards lateral and posterior. Another pair of muscles located at middle region of anterior third part (Figs. 18, 19: em), originating single in ventral region of haemocoel, running together with each other towards dorsal and posterior, separating from each other in region touching epiproboscis, inserting in both sides of outer wall. Posterior end of epiproboscis with terminal, short muscle (Figs. 17-19: me), originating in middle outer region of odontophore dorsal surface. Inner epiproboscis structure constituted by 3 similar thickened layers: inner layer of glandular tissue; intermediary layer of longitudinal muscle fibers; outer layer of circular muscle fibers (Fig. 19). Its posterior end connecting to posterior end of outer wall by means of longitudinal muscular fibers; inner glandular tissue initiating at some distance from this muscle. Connection epiproboscis-oral tube (Fig. 19: ea) presenting a duct immerse in oral tube inner wall, running distance of about half of oral tube length; its inner surface with some longitudinal, low folds. **Odontophore** muscles (Figs. 17, 18, 22-25): **mj**, pair of broad muscles, origin in middle region of cartilages outer surface, run towards anterior becoming part of oral tube, somewhat thin in origin, gradually become thick; **m2**, 2 pairs of long and narrow retractor of buccal mass muscles, originating along ventral-inner surface of proboscis, in region just posterior to odontophore detaching from proboscis, inserting in posterior surface of odontophore by side of radular sac; **m2a**, pair of narrow retractor of radular sac muscles, or



Figs 9-16 *Ziba carinata* anatomy: **9**, head-foot, right view; **10**, pallial cavity hoof and anterior region of visceral mass, ventral view; **11**, anterior region of visceral mass and adjacent region of pallial cavity, ventral view, ventral wall of kidney and pericardium removed, digestive gland covering stomach also removed, structures seen as in situ; **12**, pallial cavity hoof, transverse section in middle level of osphradium; **13**, head and haemocoel, ventral view, foot and columellar muscle removed; **14**, foot, female, ventral view (sole); **15**, head and foregut, ventral view, proboscis (pb) sectioned longitudinally, most structures artificially uncoiled; **16**, foot, female, sagittal section in its anterior region. Scales = 1 mm.

ventral tensor muscles, originating jointed to m2, inserting in lateral-posterior region of radular sac, close to radular nucleus (Figs. 22, 23); **m3d**, pair of thin muscles, running longitudinally in dorsal surface of odontophore close to median line, originating in oral tube outer surface by side of esophageal origin, inserting in posterior-dorsal surface of odontophore; **m3v**, pair similar to m3d, but broader and situated in ventral surface (Figs. 17, 20); **m4**, pair of large dorsal tensor muscle and compressor of cartilages, originating in outer surface of cartilages close to mj origin, surrounding almost entirely cartilages with subradular membrane connected along its outer surface; **m4a**, pair of ventral tensor muscles of radula, broad and thin, originating in dorsal-posterior surface of m4, running attached to subradular membrane, inserting in subradular membrane just in level of end of radula; **m5**, large pair of secondary dorsal tensor muscles, originating on outer-posterior surface of m4, running towards medial and anterior, inserting along ventral surface of radular ribbon in its region preceding its exposed (in use) portion (Figs. 24, 25); in region of m5 origin, m5, m4 and mj producing a single, thick muscular mass (Fig. 25); **m6**, horizontal muscle thin and short, connecting both cartilages along their anterior  $\frac{1}{4}$  length; **m7**, pair of small and short muscles, originating in m4 posterior-dorsal-median edge, running a short distance, penetrating into radular sac, inserting in posterior-ventral inner surface of it; **m9**, pair of thin and broad muscles, originating in m4 dorsal-median surface, running towards medial and posterior, inserting along tissue on radula preceding its exposed area, along median line (Figs. 23, 24). Odontophore cartilages separated from each other; each one thick, weakly flat, soft, fusiform, 6 times longer than wide; anterior and posterior extremities rounded. Subradular cartilage (connected to subradular membrane) extending little beyond radular ribbon, less than half of its area (Fig. 22: sc). **Radula** with about 1.5 times odontophore length. Radular teeth (Figs. 6-8): **rachidian** occupying about  $\frac{1}{5}$  of radular ribbon width, somewhat rectangular, about double wider than long, 6 sharp pointed cusps, being weakly larger towards medial, each cusp separated from each other by distance equivalent to their width, both lateral cusps about half sized than other cusps (Fig. 7); **lateral teeth** with about double of rachidian width and with its same length, 5 to 8 sharp pointed cusps in median half, with similar shape of rachidian cusps, appearing gradually from lateral edge and becoming broader towards medial, penultimate cusp larger, last (medial) cusp with about half of size of penultimate cusp and located slightly below it, cusps turned inwards. **Salivary glands** clustering around esophagus just posterior to nerve ring (Figs. 13,

15: sg). Salivary ducts long, pale green, iridescent, convolute, narrow, running along esophagus up to its origin in buccal mass (Fig. 15: sd). Salivary aperture in both sides of esophageal origin, bordered by a pair of small and low folds (Fig. 20). No accessory salivary glands. **Esophagus** narrow since its origin, about 1.5 whorls long; inner surface with about 8 longitudinal, narrow, low folds, yellowish, iridescent, lacking any special glands or valve. Gland of Leiblein absent. **Stomach** simple, curved; large duct to digestive gland single, located in its middle-anterior gastric side (Fig. 11: st). Anterior region of stomach preceded by thick and broad sphincter, with about half of stomach length (Fig. 11: gm). Inner surface of this sphincter with some tall folds, continuation of those from esophagus. Stomach walls thin, inner surface smooth, covered by chitin. **Intestine** with about half of stomach width, abruptly penetrating inside kidney chamber (Fig. 11: in), possessing a loop in this region; after penetrating in ventral renal lobe, running straight forward. Rectum and anus above described (pallial cavity).

**Genital system. Female.** (No males examined.) Both females examined possessing immature genital systems, precluding any detailed analysis. Pallial oviduct running ventrally by side of rectum, entirely closed (tubular). Cement gland orifice in foot sole (Fig. 14: fg) located in its anterior third part, transversely elongated; internally a broad and flat chamber, surrounded by thin glandular walls (Fig. 16: fg), length about half of local foot thickness. This chamber connecting to outer orifice by a broad, flat duct running perpendicular to sole (Fig. 16).

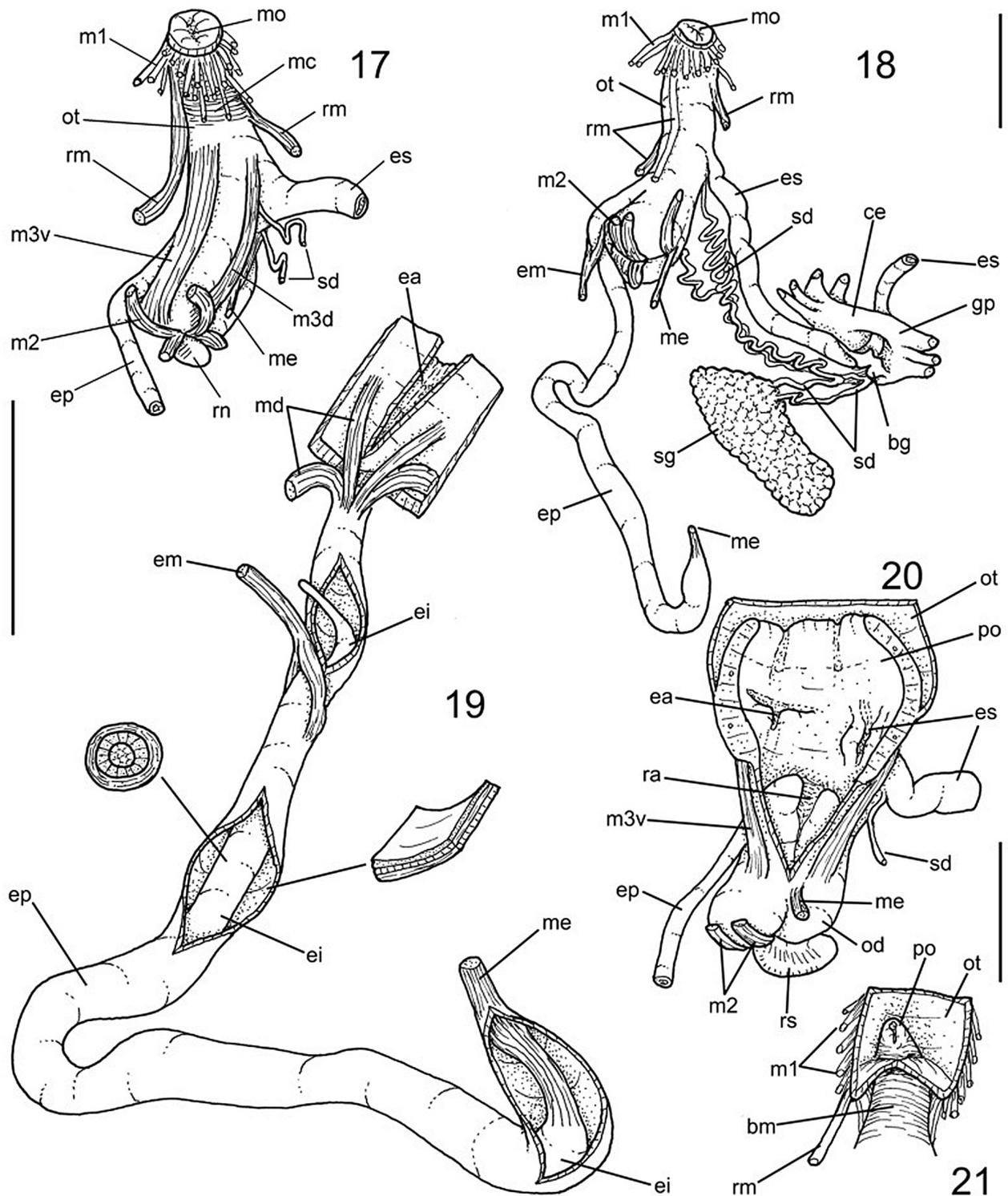
**Central nervous system** (Figs. 15, 18, 26). Highly concentrated, ganglia mostly fused, of difficult differentiation, somewhat asymmetrical. Pair of buccal ganglia situated close and dorsal to nerve ring, with short connectives to it. Supra- and sub-esophageal ganglia also situated close to nerve ring. Pair of statocysts close with each other and having a single, large statolyth. Both statocysts situated in anterior region of haemocoel right edge, immerse in foot musculature, connected to pedal ganglia by a long and narrow connective.

**Measurements** (in mm). #1) 16.0 by 5.3; #2) 13.0 by 4.1; #3 (Fig. 1-3): 18.1 by 5.4.

**Distribution.** West coast of Africa, from Senegal to Angola.

**Habitat.** In rubble, about 25-30 m depth.

**Material examined.** GHANA; Western Region, off Mudrachmi Bay, 25 m depth, MZSP 94071, 2♀, 1 shell (Figs. 1-3) (dredged in rubble, ii/1999).



Figs 17-21 *Ziba carinata* anatomy: **17**, buccal mass, left view; **18**, foregut, left view, most structures artificially straightened; **19**, epiproboscis and adjacent region of buccal mass, ventral view, some longitudinal sections done in some portions for showing inner structures, a transverse section in indicated level and a detail of outer wall also shown; **20**, buccal mass, left-slightly dorsal view, oral tube (ot) sectioned longitudinally; **21**, oral tube, ventral view, outer wall sectioned longitudinally for showing muscular projection (po) inside it. Scales = 1 mm.



including the epiproboscis (Fig. 19), which is the structure that distinguishes the family Mitridae from the ally, and previously fused, family Costellariidae (Ponder, 1972, 1998; Harasewych, 2009). The lack of accessory salivary glands and the gland and valve of Leiblein, typical neogastropod structures, is common in mitrids, the function(s) of these are possibly replaced by the epiproboscis. This adaptation is possibly connected to predation on sipunculans (Taylor, 1993) and, more rarely, nemerteans (Fukuyama & Nybakken, 1983). The epiproboscis action, function and use has been long debated in the literature (Vayssière, 1901; Risbec, 1928; Cernohorsky, 1970; Loch, 1987; Taylor, 1989; West, 1990; Harasewych, 2009), however this topic is outside the scope of the present study. The epiproboscis appears to be a modification of the salivary ducts, which can be protruded for predation (Ponder, 1972). However, *Ziba carinata*'s epiproboscis appears to lack any internal duct, being solid and composed of muscular and glandular tissue. Similar structures are known for other mitrids (Ponder, 1972, fig. 1B).

The extrinsic musculature of the epiproboscis of *Ziba carinata* looks similar to other mitrids. Nevertheless, the epiproboscis middle muscle (Fig. 19: em) is apparently absent in other species; or it can be mixed with the 'ventral odontophoral retractor muscle' (Ponder, 1972: v.od.r. in fig. 1A) (here called m2) of *Strigatella* spp. The muscle of distal end of epiproboscis (Fig. 19: me), connecting it to the ventral region of odontophore, is clearly shown by Ponder (1972, Fig. 1A, 9A-C), but it is not indicated or named. Still in the foregut region, as *Ziba carinata* lacks an introvert, it may not be linked to the mitriform genus *Pleioptygma* Conrad, 1863 (Quinn, 1989).

The esophagus of the mitrids is normally simple, contrasting with the complex esophagi of the costellariids and other related families (Ponder, 1972; Simone 1995), possessing glands, chambers and valve. *Ziba carinata* also has a simple esophagus.

Another common feature of mitrids is the thick hypobranchial gland (Harasewych, 2009), which *Ziba carinata* also possesses (Figs. 10, 12: hg). Other anatomical features that are typical of the mitrids (Ponder, 1972), also found in *Z. carinata*, include the anal gland, columellar plaits, and the lack of operculum. However, the anal gland is very weak, and the hypobranchial gland lacks the purple secretion in this species, typical familiar attributes; though, the preservation of the samples can be responsible for those discrepancies. The characteristic mitrid kidney has been described as possessing primary and secondary lamellae (Ponder, 1972), which *Z. carinata* also has.

*Ziba* was described as subgenus of the genus *Turricula* Klein, 1753 (pre-linnean name, also preoccupied by *Turricula* Schumacher, 1817, a turrid) encompassing 6 species (Adams & Adams, 1853: 179). One of them was *Z. carinata*, which was subsequently designed as type of the taxon (Wenz, 1938: 1292), as subgenus of *Mitraria* Rafinesque, 1815. This is an example of the inconstancy of the mitriform taxonomy. The generic status of *Ziba* appears to have been introduced by Cernohorsky (1970: 47). Representatives of the genus *Ziba* present a close similarity with species attributed to other genera, such as *Cancilla* Swainson, 1840; and *Subcancilla* Olsson & Harbison, 1953. Representatives of those genera are still being anatomically analyzed. Future detailed comparisons among these genera will possibly provide a better definition of these taxa.

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