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Two species of *Fridericia* Mich., 1889 (Oligochaeta, Enchytraeidae) from Brazil.

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SUMMARY

Two species of enchytraeid worms common in the State of São Paulo, *Fridericia bulbosa* (Rosa, 1887) and *F. bollonsi* Benham, 1914, were studied regarding their anatomy and taxonomy. Three varieties of *F. bulbosa* were recognized which, in a general manner, present the following differences: variations in body size, difference in number of body segments and setae, dissimilar disposition of clitellar and chylus cells, variety in shape of spermathecae, peptonephridia and septal glands, different points of origin of ectal ducts on nephridia and of dorsal vessel and, finally, difference in size of seminal funnels and of penial bulbs.

RESUMO

Foram estudadas anatomica e sistematicamente *Fridericia bulbosa* (Rosa, 1887) e *F. bollonsi* Benham, 1914, comuns no Estado de São Paulo. De *F. bulbosa* foram reconhecidas três variedades que, de um modo geral, diferem pelo tamanho, número de segmentos e de cerdas, disposição das células clitelares e quilíferas, forma das espermatecas, dos peptonefrídios e das glândulas septais, pela origem do duto excretor nos nefrídios e do vaso dorsal, assim como pelo tamanho dos funís seminais e dos bulbos peniais.

Being interested in the Oligochaeta, Enchytraeidae, I studied the anthropochorous species, which must be very plastic, anatomically and/or physiologically, to adapt themselves to the new biotopes into which they are introduced by man. Only when the intraspecific differences in the various geographical regions are compiled, will it be possible to establish with certainty the degree of variability of these peregrine species and consequently their synonymy. With this purpose, the most frequent species in São Paulo were studied anatomically.

The worms were observed alive and thereafter anesthetized in alcohol 10%. The ones from São Paulo were fixed in Bouin and those from

other localities in formalin 10%. Some specimens were stained with Mayer's Paracarmin; for structural details serial sections were made and stained with Ehrlich's Hematoxilin and Eosin. The material is deposited in the Zoological Department, University of São Paulo (ZU).

Fridericia bulbosa (Rosa, 1887)
(Figs. 1-15)

Neonchytraeus bulbosus Rosa, 1887: 2. *Fridericia bulbosa* Michaelsen, 1889: 42; 1900: 96; 1924: 383; 1927: 369; Ude, 1892: 78, figs. 2-4; 1929: 64; Beddard, 1895: 343; Bretscher, 1899: 406; 1903: 8; 1904a: 263; 1904b: 501; Cognetti, 1901: 11; Issel, 1905a: 463; 1905b: 5; Southern, 1907: 72, figs. 7A-D; Stephenson, 1911: 31; 1914: 334; 1923: 111; Dequal, 1914: 14; Knöllner, 1935: 443; Cernosvitov, 1937: 198; 1938: 284, figs. 32-34; 1941: 259; Schmidegg, 1938: 26; Bell, 1942: 404, figs. 1-6; 1962: 158; Backlund, 1946: 9, figs. 3,8; Büllow, 1955: 259; Nielsen & Christensen, 1959: 72, fig. 71; 1961: 9; 1963: 14; Botea, 1962: 404; Christensen, 1962: 4; Nurminen, 1964: 50; 1965a: 3; 1965b: 14; Gunst, 1965: 9; Radu & Stefan, 1968: 75; Rao, 1969: 89. *F bulbosa* var. (*nec nom.*) Michaelsen, 1907: 2. *F parva* Moore, 1895: 343, figs. 9-10; Bretscher, 1902: 8; 1903a: 7; 1903c: 32; 1904a: 263; 1904b: 501; 1905: 666. *F. rosae* Cognetti, 1899: 1. *F variata* Bretscher, 1902: 19; 1903a: 8; 1903b: 117; 1903c: 32; 1904a: 263; 1904b: 501; 1905: 666; Southern, 1907: 73, fig. 8; Piguet & Bretscher, 1913: 123. *F. sp.* (? *bisetosa*) Michaelsen, 1905a: 19; 1905b: 310. *F breiscberi* Southern, 1907: 73, figs. 9A-B; Piguet & Bretscher, 1913: 122. *F pulchra* Friend, 1911a: 415; 1912a: 21, figs. 9-10. *F obtusa* Friend, 1911b: 61; 1913: 267. *F pseudobulbifera* (nom. nud) Friend, 1912b: 28. *F bulbifera* Friend, 1912b: 33; 1913: 255; 1914: 141. *F magnisetosa* Friend, 1913: 255. *F peregrinabunda* Michaelsen, 1913: 408. *F carmichaeli* Stephenson, 1915: 47, figs. 3-5.

Material:

Brazil, São Paulo: São Paulo, Cidade Universitária, 40 specimens (ZU-334), M. L. Christoffersen col. XI.1973-II.1974; Iporanga, Upper and Lower Alambari caves, on the banks of the Alambari river, 6 specimens (ZU-335), M. L. Chritoffersen col. XII.1973; Mogi das Cruzes, 2 specimens (ZU-336), H. Verdi col. III.1974.

In an area of 20 m² at the campus of the University of São Paulo 3 different varieties were recognized, referred to below as *A, B* and *C*. *A* was found in humid black clay, *B* in relatively dry brown earth, and *C* between decaying leaves. There are no distinct limits in the distribution of the varieties and some specimens display intermediate characters.

In preserved specimens the ratios total length of animal: width of clitellum in millimeters are in *A* 7-9:0,22-0,27, in *B* 10-13:0,27-0,32 and in *C* 11-15:0,38-0,43. The number of segments is 34-46, 37-51 and 41-57, respectively.

The setae are straight and an ental hook is poorly developed or absent. In *A* and *B* there are 4 setae per bundle up to the middle of the worm, whereupon the number decreases to 3 and near the posterior segments to 2. In *C* the number of setae in the anterior ventral bundles varies from 4 to 6 (Fig. 1). The posterior setae are always the longest, attaining 60 μm in *A* and *B* and 95 μm in *C*.

The head pore is located at 0/1 and the dorsal pores begin in VII. Cutaneous glands may be inconspicuous or form up to 4 transversal rows per segment. They are especially distinct in the anterior region of *B*. In *A* there is a single transversal row of large cutaneous glands between the setal bundles. The annular clitellum extends over XII-1/2 XIII. The gland cells have an irregular outline and are arranged in 25-30 distinct rows in *A;* the regularity is partially lost in *B* and totally in *C*. There is a pair of female pores in the posterior region of XII (Fig. 5), in line with the ventral setae; these are slightly elevated and surrounded by cells which are narrower and stain more densely with Eosin than the clitellar cells.

Pairs of septal glands (Fig. 2) are located on septa 4/5 to 6/7. Their ventral lobes are developed in 5/6 and 6/7, mainly in the latter; these are rounded and situated anteriorly to the corresponding dorsal lobes, to which they are connected by an S-shaped glandular band. The ventral lobes of 5/6 surpass slightly the anterior limits of the dorsal lobes. In the first pair of glands, the ventral lobes are missing or are only slightly developed in *C*. The symmetrical dorsal lobes of 6/7 are independent; those of 5/6 are united by a narrow band, although in *C* they are sometimes free; in 4/5 the connecting band reaches from half to almost the entire width of the lobes in *A* and *B,* whereas in *C* the connection is made with only one third of the width.

The peptonephridia are tubular and of irregular shape, opening ventrolaterally into the posterior region of the pharynx. They reach the anterior portion of segment VI in *A,* and the posterior part of VI or anterior of VII in *B* and *C*. In *A* (Fig. 4) they are either undivided or have 2 or 3 terminal lobes. In *B* (Fig. 8) they are either undivided or bifurcate; in the latter case one branch is usually shorter than the other. One specimen had 3 branches. In *C* (Fig. 6) they are usually bifurcate posteriorly, with branches measuring on an average 85 μm, but there may be 3-4 posterior branches, some shorter than others. The disposition of the peptonephridia in *B* and *C* varies. They may be directed backwards, with branches reaching VII, bent upwards in V, with branches lying next to the spermathecal ducts, or double backwards so that one or two branches reach segment III or even II. The oesophagus passes gradually into the intestine. Chylus cells occupy 2 to 3 successive segments in *A* and *B,* their exact location varying from anywhere between somites XII to XV in *A* and from XIII to XVI in *B*. In *C* the chylus cells occupy 3 to 4 successive segments in the range of XIII to XVII.

The coelomic corpuscles are of two kinds. The bigger ones are nucleate and have an average size of 50 μm. The smaller ones are anucleate and measure 5 μm. The nucleate corpuscles have their protoplasm richly granulated in *A* and *B,* and poorly granulated in *C*. In the body cavity there is also a varying number of loose setae and setal frag-

ments, sometimes forming small aggregates with coelomic corpuscles in anteclitellar segments of *B* and *C*. The dorsal blood vessel may arise anywhere from XVI to XIX, more commonly in XVIII, in *A* and *B*, and from XVIII to XX, usually XX, in *C*. The cerebral ganglion (Fig. 7) has lateral margins which are parallel or converge slightly forward, a convex anterior margin and a convex, straight or concave posterior margin. Its length is 1 1/2 to 2 times its width. The measurements vary from 120-170 μm in length and from 55-85 μm in width.

The nephridia begin at 6/7. The anteseptal portion contains the nephrostome and some coils of the nephridial canal. The coils are more numerous and distinct in the postseptal portion. The length of the postseptal varies from 1 1/2 to 2 times that of the anteseptal. In the preclitellar nephridia (Fig. 14) the ectal ducts arise midventrally on the postseptal. In the postclitellar nephridia the origin is successsively posterior, being terminal or subterminal in the posterior half of the worm in *A* and *B* (Fig. 9); in *C* the duct originates midventrally in almost all the length of the worm, being subterminal in the last segments.

Sperm morulae and mature sperm cells occur in XI, sometimes assuming a reddish-brown colour in *B* and especially in *C*, where they occur in larger numbers and make the septum 10/11 bulge forwards, so as to fill half the cavity of somite X. The sperm funnels (Fig. 3) appear as short cylinders 1 1/2 to 2 times longer than broad. They measure 60-120 μm in length by 40-60 μm in diameter in *A*, 110-130 by 55-85 μm in *B*, and 110-200 by 55-115 μm in *C*. A tuft of sperm is attached to a well developed collar, the diameter of which is half that of the funnel. The sperm ducts are irregularly coiled in XII, leading to a pair of penial bulbs two times longer than wide and whose average length in fixed worms is 85 μm for *A*, 100 μm for *B* and 120 μm for *C*. The bulbs (Fig. 15) are of the lumbricillid type with only one type of glandular cells enclosed by a muscular sheath.

In XII there are a number of egg masses (Teilovaria) and usually one well differentiated egg cell. The spermathecae open at the surface in intersegment 4/5 without associated glands, except for superficial glandular cells which surround the ectal orifice of *B*. The ampullae are devoid of diverticula and the ental openings into the oesophagus are always independent and dorso-lateral in V Each spermatheca of *A* (Fig. 12) has a pearshaped ampulla 30 by 30 μm where it is largest and an ectal duct 6-8 times longer. The ampullae are located one in front of the other on the same side of the worm, either right or left; in the remaining varieties the disposition is symmetrical. In *B* (Fig. 13) each ampulla is 60-80 μm long by 40-50 μm wide; the bulbous portion narrows gradually towards the oesophagus. The ectal duct is 3-4 times longer than the ampulla. In *C* (Fig. 10 and 11) the bulbous portion of the ampulla is 40 μm long by 43-50 μm wide, being prolonged into a clearly delimited ental portion 40 μm long and wide (Fig. 10) or 80 μm long and 15-20 μm wide (Fig. 11). Thus the total length of the ampulla is 80-120 μm and the ectal duct is 2 1/2 to 3 1/2 times as long.

The worms from the Upper Alambari cave belong to the variety *A*, those from the Lower Alambari cave belong to *B* and those from Mogi das Cruzes to *C*.

Discussion:

The definition of *F bulbosa* is difficult due to the variability of the structures that in other species are good taxonomic characters. No exact correspondence with descriptions in literature could be found and morphological differences could not be related to the geographic distribution. This seems to prove that variations are individual, attributable to differences in gene frequencies.

F bulbosa distinguishes itself from some of the other species of *Fridericia* without diverticula on the spermathecae by the absence of seminal vesicles and by the independent communication of the spermathecae with the oesophagus. From the data in literature and my observations, it follows that the remaning characteristics that define the species are: length 4-18 mm; number of segments 25-70; number of setae per ventral preclitellar bundles 2-6 and dorsal preclitellar bundles 2-4; dorsal blood vessel between XVI and XXI, but in *F. carmichaeli* in XV (Stephenson, 1915: 48); chylus cells extending over 2-4 somites between XI-XVII, except in *F carmichaeli* (*l.c.*) occupying segments XIV to XVIII; relationship ante:postseptal of nephridia 1:1-3; relationship length: width of sperm funnels 1 1/2-3:1, but Southern (1907:73) indicates 3-6:1.

The species *F alba* Moore, 1895, and *F alpina* Bretscher, 1899, could not be distinguished with certainty from *F bulbosa*. Their definite inclusion as synonyms of *F bulbosa* depends upon the study of the types.

Geographical distribution:

South Sumatra and West Java (Michaelsen, 1924: 384); St. Paul and Amsterdam Islands (Michaelsen, 1905a: 19); India: Wagah (Stephenson, 1914: 334; 1923: 111). Darjiling District (Stephenson, 1915: 47), Orissa (Rao, 1969: 89); Zanzibar Island (Michaelsen, 1905b: 310), Natal (Michaelsen, 1907: 2; 1913: 408); Uganda (Cernosvitov, 1938: 284); Armenia (Nielsen & Christensen, 1959: 72); Romania (Radu & Stefan, 1968: 75; Botea, 1962: 404); Italy: Turin (Rosa, 1887: 3; Cognetti, 1899: 1), Val Pellice (Issel, 1905a: 463), Cortina d'Ampezzo (Nielsen & Christensen, 1961: 9; 1963: 14), Florence (Dequal, 1914: 14), Elba Island (Issel, 1905b: 5), Sardinia (Cognetti, 1901: 11); Switzerland (Piguet & Bretscher, 1913: 123); Austria (Schmidegg, 1938: 26); Germany: Schlei (Köllner, 1935: 443; Bülow, 1955: 259), Calefeld, Goslar (Michaelsen, 1900: 96); Netherlands: Beuningen (Gunst, 1965: 9); Denmark (Nielsen & Christensen, 1959: 72); Sweden: Skåne (Backlund, 1946: 9); Norway: Tromsø, Tromsdalen, Oteren, Laksvatn, Lyngenfjorden, Nordreisa, Altudet, Langfjord, Talvik, Gargia (Nurminen, 1965b: 14); Finland: Jumpajoki, Hyyträlä, Kittilä, Pallasjarvi (Nurminen, 1964: 50); Spitzbergen (Nurminen, 1965a: 3) Novaya Zemlya (Southern, 1907: 73); Iceland (Christensen, 1962: 4); Ireland (Southern, 1907: 72); Scotland: Clyde (Stephenson, 1911: 31); England: London (Backlund, 1946: 10), Nottingham, Mansfield, Wells (Cernosvitov, 1937: 198; 1941: 259); Madeira Island (Bell, 1962: 158); St. Helen Island (Michaelsen, 1950a: 19); USA: Philadelphia (Moore, 1895: 343), Arakansas (Bell, 1962: 158);

Mexico (Bell, 1942: 404); Brazil (Michaelsen, 1927: 369), Iporanga, São Paulo and Mogi das Cruzes.

Fridericia bollonsi Benham, 1914
(Figs. 16-25)

Fridericia bollonsi Benham, 1914: 175, figs. 1-6.

Material:

Brazil, São Paulo: São Paulo, Cidade Universitária, 15 mature specimens (ZU-337), M. L. Christoffersen col. XII.1973; Birigui, 6 mature and 4 immature specimens (ZU-257), I. Mimura col. 16.VIII.1972; Pirassununga, 8 mature specimens (ZU-258), I.N. Cipolli col. VI.1972.

The Pirassununga and Birigui worms are from 13,5 to 14,5 mm long, from 0,35 to 0,5 mm wide in the middle region of the body and from 0,5 to 0,7 mm wide in the clitellar region; there are from 59 to 63 segments. The São Paulo worms are longer, measuring from 17 to 22 mm in length, and the width is approximately the same in the clitellar and middle regions, measuring from 0,35 to 0,5 mm; 59 to 64 segments were observed in all but two worms, which had 71. There are 2 setae per bundle, but occasionally there are 3 or 1 in some segments. The setae (Fig. 20) are straight, with ental end slightly bent. In the middle region of the body the average length of the dorsal setae is 55 μm and of the ventral setae 60 μm; the posterior setae are the longest, attaining 85 μm. The clitellum covers segments XII-1/2 XIII, having cells arranged in more or less regular bands in the dorsal and lateral regions, being irregular between the male pores. In the posterior region of XII there is a pair of female pores. Cutaneous glands are hardly distinct. Dorsal pores begin in VII and the head pore is located at 0/1.

The dorsal blood vessel arises in XIX in the Pirassununga and Birigui worms, and between XX and XXII in those from São Paulo. The bigger coelomic corpuscles are nucleate and rich in granules, measuring 55-60 μm. Definite aggregates of these corpuscles occur from VII to IX, surrounding setae and setal fragments. In the anterior nephridia (Fig. 24), the postseptal is 1 1/2 to 2 times bigger than the anteseptal, these two regions being separated by a distinct constriction at the height of the septum. In the posterior nephridia (Fig. 25) there is no constriction and the two parts are approximately equal in length. The nephridia are smaller towards the posterior end of the worm. Those in front measured 230 μm and the ones at the back 130 μm. The ectal duct arises from any point of the anterior ventral two-thirds of the postseptal. Its length is equal to, or a little longer than, the total length of the corresponding nephridium.

The cerebral ganglion (Fig. 19) has parallel lateral margins, a straight or slightly convex anterior margin and a straight, concave or somewhat convex posterior margin. The length varies from 150 to 180 μm and the width from 85 to 100 μm.

The symmetrical septal glands from IV to VI (Fig. 16) consist of dorsal lobes and smaller ventral lobes, which are missing or very reduced

in IV. The ventral lobes of the third pair connect to the corresponding dorsal lobes by an S-shaped glandular band. The three pairs of glands fuse dorsally by bands that are successively narrower from the first to the third pair. The peptonephridia open ventrally into the oesophagus in IV In the worms from Birigui each peptonephridium (Fig. 23) emits a lateral branch in the middle portion of IV, which perforates the septum 4/5, and bifurcates right after. The branches, one of which is shorter than the other, arise alongside the septal glands of V. The ventral portion of the peptonephridium stops short of septum 4/5 or perforates it, ending up in two small lobes just beyond the septum. The material from São Paulo and maybe also that from Pirassununga differs because the organs only branch out near their posterior ends in V (Fig. 22). The oesophagus passes gradually into the intestine. Chylus cells are located from XIV to XVII in the worms from Birigui and Pirassununga; in those from São Paulo they occupy 3 to 4 successive segments anywhere between XIII and XVIII.

A dense mass of reddish-brown sperm cells fills segments X and XI. The sperm funnels (Fig. 17) are coneshaped and approximately 1 1/2 times longer than their broadest diameter; the measurements vary from 200 to 280 μm and from 130 to 150 μm, respectively. The sperm ducts are restricted to segment XII. Each penial bulb (Fig. 18) is ovoid, its bigger axis being longitudinal; it measures an average of 140:100 μm. In the retracted bulb the penial invagination is very large, but shallow, with a thick cuticular coating on the lateral wall, where 2 or 3 ental recesses are found. On the medial wall no cuticle was recognized and so this seems to end at the height of the lip. The sperm duct enters the bulb laterally and continues as a narrow penial lumen through the middle of the bulb, opening out into the internal half of the penial invagination. The bulbs are of the lumbricillid type, with a muscular layer over two groups of glandular cells. The more peripheral gland cells have a densely stained protoplasm and lead from the medial wall into the penial invagination. The more internal cells, surrounded by the former, have a more hyaline protoplasm and lead into the penial lumen.

In the cavity of XII there are some egg masses (Teilovaria) and up to two well differentiated eggs that slightly distend the septa 11/12 and 12/13, without forming a typical egg sac. Each spermatheca (Fig. 21) has a pyriform ampulla opening independently into the oesophagus through the lateral wall of the latter. The lenght of the ampulla varies from 120 to 140 μm and the biggest diameter from 60 to 70 μm. Surrounding the opening of the ectal duct into the ampulla there is an annular region with thinner walls than the rest of the ampulla, and here the sperm cells are stored. The annular constriction indicated by Benham (1914: 178) is more evident in the worms from Pirassununga. In serial sections, the organization of the ampulla is identical to that observed by Benham. The ectal duct is about 1 1/2 times longer than the ampulla and there are no glands at the ectal opening.

Discussion:

F bollonsi Benham, 1914, is very similar to *F bulbosa* (Rosa, 1887), particularly to the variety described as *F peregrinabunda* Michaelsen,

1913. They are not synonyms as suggested by Backlund (1946: 9), differing mainly by the spermathecae, penial bulbs and sperm funnels.

Geographical distribution:

Kermadec Islands (Benham, 1914: 174); Brazil: São Paulo, Pirassununga and Birigui.

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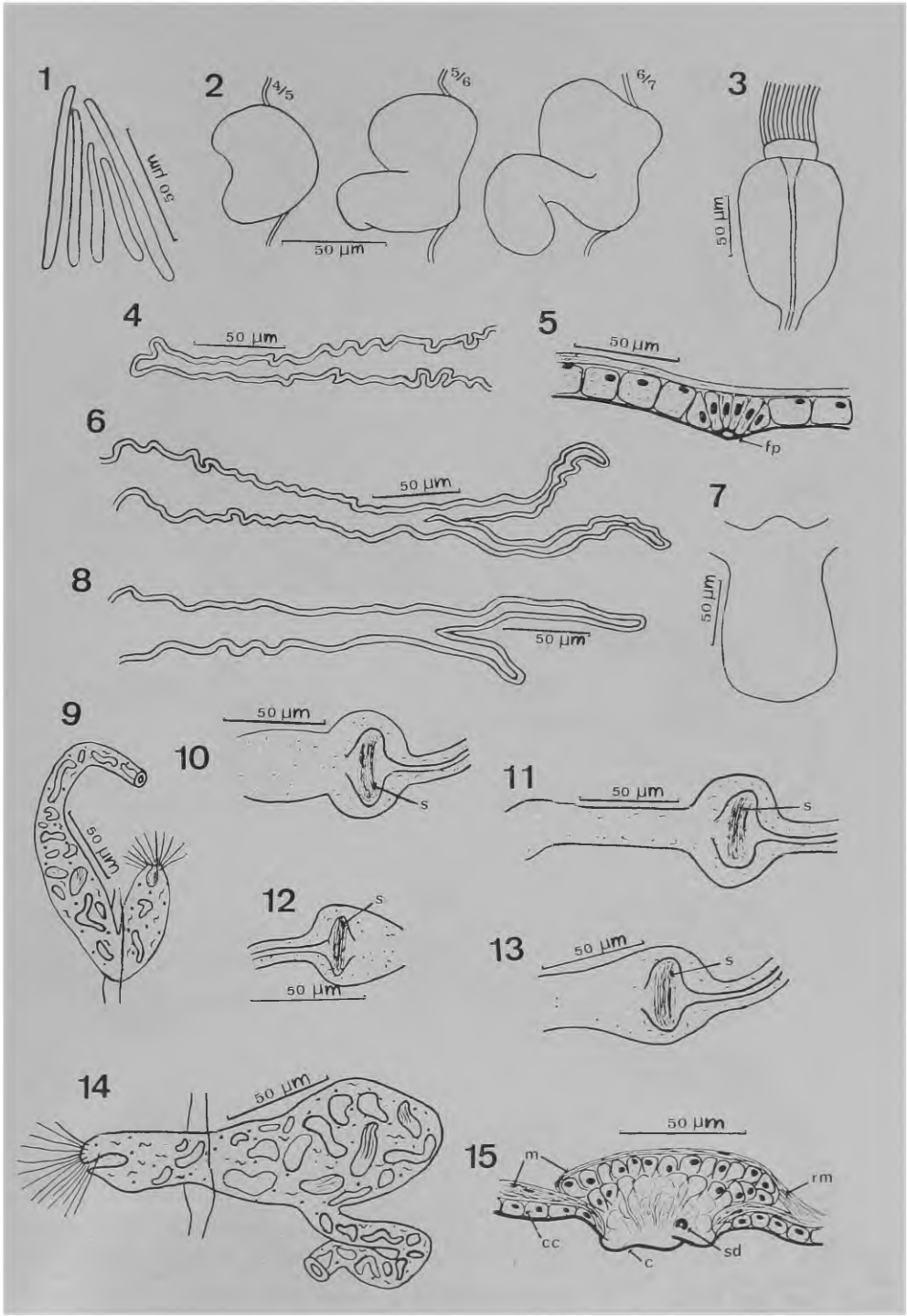
Figs. 1-15 — *Fridericia bulbosa* — 1. Ventral setae of segment VII, variety *C*. — 2. Septal glands, variety *C*, lateral view. — 3. Sperm funnel, variety *B*. — 4. Peptonephridium, variety *A*. — 5. Feminine pore, variety *B*, longitudinal section. — 6. Peptonephridium, variety *C*. — 7. Cerebral ganglion, variety *C*, dorsal view. — 8. Peptonephridium, variety *B*. — 9. Nephridium of segment XIX, variety *A*. — 10. Spermatheca, variety *C*. — 11. Spermatheca, variety *C*. — 12. Spermatheca, variety *A*. — 13. Spermatheca, variety *B*. — 14. Nephridium of segment VII, variety *B*, lateral view. 15. Penial bulb, variety *B*, longitudinal section.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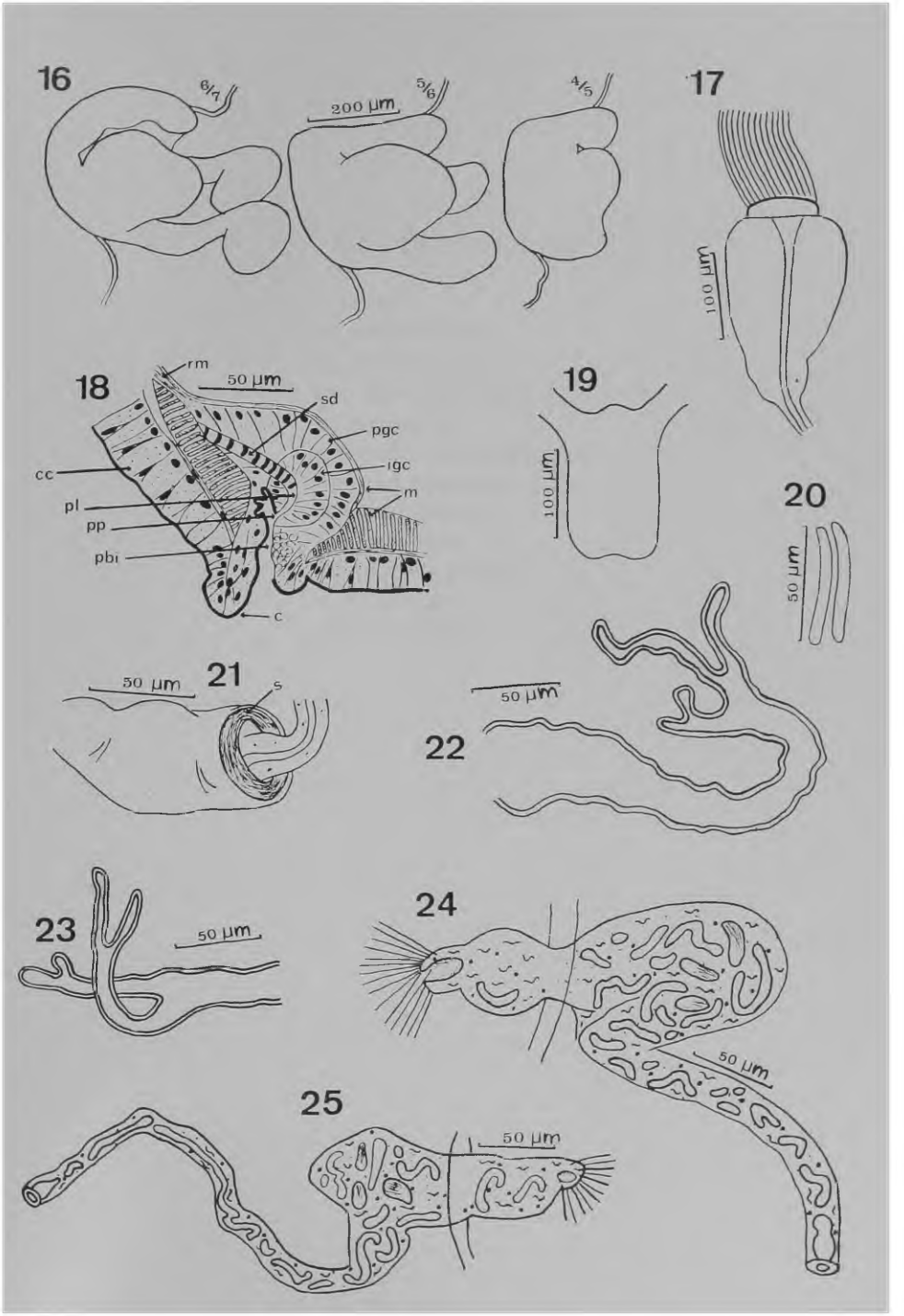
Figs. 16-25 — *Fridericia bollonsi* — 16. Septal glands, dorso-lateral view. — 17 Sperm funnel. — 18. Penial bulb, transversal section. — 19. Cerebral ganglion, dorsal view. 20. Ventral setae of segment VII. — 21. Spermatheca. — 22. Peptonephridium in worm from São Paulo. — 23. Peptonephridium in worm from Birigui. — 24. Nephridium of segment VII, lateral view. — 25. Nephridium of segment XXXIV, lateral view.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ABBREVIATIONS

c, cuticle.
cc, clitellar cells.
fp, feminine pore.
igc, inner gland cells.
m, musculature
pbi, penial bulb invagination.
pgc, peripheral gland cells.
pl, penial lumen.
pp, penial pore.
rm, retractor muscle.
s, spermatozoa.
sd, sperm duct.