Dept. of Zoology,
Fac. of Sciene (Sohag), Assiut Univ. Egypt.
Head of Dept. Prof. Dr.

ON THE RESPIRATORY AND NERVOUS SYSTEMS OF DOSINIA RADIATA (MOLLUSCA: BIVALVIA) FROM THE RED SEA

(With 4 Fig. & 2 Plate)

By

H.M. ABOUL-DAHAB; M.R. EL-HELW
A.E. YASEEN and G.S. AMIN

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الجهازين التنفسى والعصبى لمحار دوزينيا راديانا /رخويات : ذوات المصراعين/

حسنى أبو الدهب ، محمد الحلو ، أحمد يس
جمال الدين أمين

تبين من هذه الدراسه ان الجهاز التنفسى لمحار دوزينيا راديانا يتركب من خيشوم عريض بيضاوى الشكل على كل جانب ، وكل خيشوم يتركب من نصف خيشوم خارجى واخر داخلى .

ولقد وجد ان نصف الخيشوم الخارجى اقصر فى الطول والعرض وعدد الخيوط الخيشوميه عن نصف الخيشوم الداخلى .

كما بينت الدراسه ان نصفى الخيشوم على كل جانب يلتحمان من الناحيه الخلفيه الظهريه بواسطة زائده فوق خيشوميه . ولقد وجد ان الطرف النهائى لكل نصف خيشوم به ميزاب مهدب يمتد بطوله لنقل المواد المخاطيه والغذائيه الى منطقة الفم .

ولقد سجلت الدراسه ان الجهاز العصبى يتركب من ثلاثة ازواج من العقد العصبيه هى المخيه والحشويه والقدميه تتصل فيما بينها بواسطة اعصاب رئيسيه .

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*: Dept. Genetic, Fac. of Agriculture (Assiut), Assiut Univ., Egypt.
**: Dept. Zoology, Fac. of Science (Quena), Assiut Univ., Egypt.

SUMMARY

Dosinia radiata has flat ctenidia. Each ctenidium consists of outer and inner plicated demibranchs. The outer demibranch is shorter in length and width than the inner one and has distinct supra-axial extension throughout the length of its dorsal margin. The inner demibranch is deeper dorso-ventrally and antero-posteriorly with semicircular to ovoid shape. The lamellae of the outer and inner demibranchs are pelicated. The gills of D. radiata have a well developed and ciliated groove at the free edge of each demibranch (type C 2). The basic structure of the nervous system of Dosinia radiata, as in other species of Bivalvia, consists of three pairs of ganglia; cerebral, visceral and pedal which are connected with each other by cerebropedal and cerebroviseral connectives.

INTRODUCTION

The genus *Dosinia* is a widely distributed clam around the world (Fig. 1A). It contains large number of handsome and beautifylly coloured species. It has an economical importance, where, the flesh of larger sized individuals is eaten in different parts in the world and their shells could be used for industrial purposes. *Dosinia radiata* is a common species in sandy shores of the Red Sea coast. It can be easily differentiated by large number of pores made on the sand by siphons during their vertical movements.

The literatures on the respiratory system of Bivalvia is extensive. *ATKINS (1937)* studied types of Lamellibranch gills and their food current. *HEBLING (1976)* reported on the functional morphology of two species of the genus *Anodontites, MARSHALL and WILLIAMS (1972)* wrote on the ctenidia and water circulation in *BIVALVIA, MORTON (1973 a, b, c, 1974, 1977)* reported about the ctenidial structure and function of *Limnoperna* fortunei, *Musculista senhausia and Modiolus metcalfei and YONGE (1973, 1977)*, studied the structure and function of ctenidia of *Spondylus americanus and Plicatula*

gibbosa. *NARCHI (1974)* reported on the structure and function of ctenidia of the bivalve *Petricola typica and Fretter and GRAHAM (1976)* on the ctenidial structure and function of some members of Lamellibranchiata and more recently, *ABOUL-DAHAB (1984)* studied the gill structure of *Modiolus auriculatus* from the Red Sea.

A review of the literatures on the nervous system of Bivalvia reveals some of early and recent works. *HILTON (1919, 1920a, b)* gave histological studies on the nervous system of 6-species of bivalve molluscs, among which are *Nucula castensis, Malleta faba and Mytilus californianus. DAKIN (1928)* gave comparative studies on the nervous system of *Spondylus goederopus and pecten maximus. GRAHAM (1931)* studied the morphology of the nervous system of *Ensis silique. YONGE (1973)* studied the nervous system of two species of *Spondylus americanus and Plicatula gibbosa. HEBLING (1976)* observed the nervous system of *Anodontites trapezeus* and *A. trapesialis. ABOUL-DAHAB (1984)* studied the nervous system of the mytilid bivalve *Modiolus auriculatus*. There is no published work on the respiratory and nervous systems of *Dosinia radiata.*

MATERIAL AND METHODS

The specimens of *Dosinia radiata* used in the present study were collected from a sandy shore placed at 54 km south of Quesir City (26° 30 N, 34° 40 E) on the Red Sea Coast (Fig. 1B). Specimens were collected, at the time of low tide about 0.0-0.5 meter depth. The collection of samples was done by the hand. Specimens were picked up and put in plastic containers with 10% formalin and taken to the laboratory for anatomical studies. All measurements for the two systems were done using calibrated occular eye peice while drawings were done with help of a camera lucida.

Paraffin sections were made by fixation of some specimens in Bouin's solution for 24 hours, washing and dehydrating them in ascending grades of alcohol, then they were cleared in xylene and embedded in paraffin. Sectioning was made at 6-7u thickness. Staining was carried out using haematoxylin and Eosin. Some sections were stained with Masson's Trichrome, Orcien, Southgat's mucicarmine, Best's carmine stains, and Periodic acid Schiff's reaction (PAS) for the demonstration of collagen, elastin, reticulin, mucine, glycogen and carbohtydrates respectively.

RESULTS

A- Respiratory system

The respiratory system of the eulamellibranch *Dosinia radiata* consists of brownish and flat ctenidia, one ctenidium on each side of the visceral mass. Each ctenidium is composed of two demibranchs (outer and inner) suspended from the visceral mass and entirely free from one another and from mantle surface (Fig. A, B, C). Each demibranch (outer or inner), extends as semicircular to ovoid plates along the mantle cavity and consists of a descending lamella and an opposite ascending one (P1.1, A). Each lamella of each demibrach appears as a sheet of parallel alternating ridges and grooves that extend from the proximal to the distal parts of each demibranch (P1.1, A, C; Fig 2. A, B).

The outer demibranch is roughly semicircular to oval in shape and shorter in width and length than the inner one (Fig. 2. A, B). It is about 18 and 11 mm for the long and short axes respectively. The number of its filaments recorded is between 30 and 32. The outer demibranch is attached postero-dorsally with a broad suspensory membrane known as supra-axial extension which is characteristic for some groups of eulamellibranchs specially those of family Veneride (P1.1, D). It measured about 13.4 x 5.85 in length and width respectively.

The inner demibranch is larger than the outer one. It is ovoid to semicircular measuring about 21 and 15 mm in length and width respectively. The number of filarments ranged from 36 to 40. It is important to note that, the anterior margin of the inner demibranch is attached with the mantle.

Cross hand sections through the visceral mass of the present species show that, only the inner demibranch appears at the anterior part of the body which is attached to the roof of the pallial cavity by its upper edge (Fig. 3,a). While sections through the posterior part of the visceral mass show that both demibranchs are found but the inner one is longer than the outer (Fig. 3,a). Aso, section shows both outer and inner demibranchs are free from one another, from mantle suface and from mantle edge.

Microscopic examinations show that the surface area of the lamellae has been increased by broad folds known as plicae (Pl.1, A). The plicae are deep and occur in both lamellae. Each plica contains from 15-40 filaments. The gills of *D. radiata*

have a well developed and ciliated groove at the free edge of each of the outer and inner demibranchs (Pl. B, C, D). The groove of the outer demibranch is slightly less deep than that of the inner one.

These characters are in accordance with those mentioned by *ATKINS (1937),* who found taht the oralward longitudinal currents pass in the marginal grooves and between the bases of the adjacent demibranchs of each side of the body. Thses currents are charged with the food particles collected from the suface of the gills and directed towards the labial palps, then to the mouth opening. In cross section, there are transverse gill bars connecting the outer and inner gill lamellae of the inner and outer demibranchs (Pl. 1, A).

Histological studies show that each lamella of each demibranch consists of a large number of filaments. Each filament consists of cuboidal cells and shows three groups of cilia (Fig. 2, D). The first group is short and located on the frontal cells of the free edge of the filament. It is about 4 um long. The second group is large and arises from the latero-frontal cells of the filament measuring about 10 um long. While the third group of cilia is the largest type and found on the lateral cells of the filament. It is about 20 um in length (Fig. 2, D). Histochemical studies revealed that the outer epithelial covering of the gill lamellae is based on fibrous basal lamina containing collagenous and reticular fibers. Also, the epithelial covering shows positive reaction for both PAS and mucoid detection (Pl. 1, C, D).

B- Nervous system

The nervous system of *Dosinia radiata* is simple, bilaterally symmetrical and it consists mainly of three paris of ganglia; the cerebral, pedal and visceral. The three groups of ganglia are connected with each other by the pallial, pedal and visceral connectives or cords (Fig. 4).

*** The cerebral gnglia:**

There is one pair of cerebral ganglia. each ganglion lies upward and lateral to the oesophagus. It is white yellowish in colour in preserved specimens while it has white bright colour in fresh specimens. It is nearly circular-shaped and meansurs about 1 x 0.83 mm in long and short axes respectively. The two cerebral ganglia are connected together by a cerebral commissure of 1.5mm length (Pl. 2,A), that runs transversely

between the two inner sides of the two ganglia passing above the oesophagus (Fig. 4).

Histologically, each cerebral ganglion consists of peripheral nerve cells enclosing a central fibrous mass which forms the suppraoesophageal commissure (Pl. 2, A).

A pallial ganglionic cord arises from the anterior end of each cerebral ganglion. It runs anteriorly for a short distance to the end of the visceral mass, then bends dowardly, bordering the ventral surface of the anterior adductor muscle. After it leaves the adductor muscle it forkes into two pallial cords, outer and inner. The outer pallial cord extends posteriorly along the peripheral region of the mantle lobe till it curves dorsally with the mantle lobe and passes anteriorly to contact with the posterior region of corresponding visceral ganglion (Fig. 4). the inner pallial cord extends posteriorly along the inner margin of the pallial muscle. It loops dorsally and ventrally at the region of the pallial sinus. Then, it extends posteriorly and curves dorsally until it connects with the visceral ganglia. Each pallial cord is bright white in colour and measuring about 6 cm long. From the pallial cord emenges a number of small nerves scattered within the pallial lobe to innervate its different parts.

The pedal ganglia:

There is one pair of pedal ganglia lying in front of the ventral margin of the coiled rectum near the base of the foot. The two ganglia are very close to each other. Their colour is white yellowish in preserved specimens and bright white in fresh specimens. Each ganglion is oval shaped being about 1.4 x 0.6 mm in long and short axes respectively. The ganglion is connected with the corresponding cerebral one by a cerebropedal cord which extends from its anterior end to the posterior inner side of the cerebral ganglion. The cerebropedal cord is white bright in colour and maesureas about 1.1 cm in length. A pair of short and thick nerves arises from the posterior end of the pedal ganglion, each extends posteriorly and downwards to innervate the foot (Fig. 4). histologically, each pedal ganglion consists of a surrounding ganglionic sheath enclosing peripherally located nerve cells and a central fibrous mass (Pl, 2, B, D).

The visceral ganglia:

On the anterior niddle margin of the ventral side of the posterior adductor muscle, there is a broad mass know as the visceral ganglia. The mass is yellowish white in colour, measuring about 1.7 x 0.7 mm in length and width respectively. The visceral mass seems to be formed by the union of the original visceral ganglia. The posteroventral ends of this mass are connected to the pallial cords previously described, while its anterolateral margins are connected with two cerebrovisceral cords. These cords extend anteriorly; passing through the kidney and visceral mass. They are parallel to each other below the integument of the visceral mass. The cerebrovisceral cords are long and white in colour, each of which measuring about 3 in length. Moreover, two nerves arise from the anterior margin of the visceral ganglionic mass and loop inside the kidney. Histologically, this mass consists of a surrounding sheath enclosing a bulk of nerve cells and nerve fibers (Pl. 2, C).

The cerebral ganglia serve for innervation of the labial palps, mouth, anterior adductor muscle and a part of the mantle. While the pedal ganglia innervate the foot. The visceral ganglia are functioned with the remaining major part of the mantle, siphons, posterior adductor muscle, gills, kidney and heart.

DISCUSSION

The respiratory system:

The venerid bivalve *Dosinia radiata* as most of other eulamellibranch has flat ctenidia; one ctenidium on each side. Each ctenidium consists of outer and inner demibranchs. The outer demibranch is shorter in length and width than the inner one and has a distinct supra-axial extension throughout the length of its dorsal margin. The inner demibranch is deeper dorso-ventrally and antero-posteriorly with a semicircular to ovoid shape. The lamellae of the outer and inner demibranchs are pelicated. Such characters are in accordance with those mentioned by Atkins (1937) for the family Veneridae.

The outher demibranch of the present species is shorter than the inner one. Similar reduction was observed in *Limnoperna Fartunei, Musculista senhausia, Modiolus metcalfei* Morton (1973, 1974, 1977) and *Modiolus auriculatus by Aboul-Dahab (1984).* Morton (1973) reported that this reduction

enables the ventral margin of food grooves of both demibranchs to be in contact with both labial palps. So, this increases the efficiency of particle selection by the palps.

The gills of *D. radiata* have a well developed and ciliated groove at the free edge of each demibranch. This agrees with type (C, 2) reported by Atkins (1937), who observed that the longitudinal currents are passed through the marginal grooves charged with food particles, collected from the surface of gills and directed towards the labial palps and mouth opening.

The gills of *Dosinia radiata* are plicated, leading to an increase in their surfaces and efficiency for function. Plicated gills are a diagnostic character for some lamellibranchs as cokles, razor clams, scallops and oysters (Barnes, 1982). The presence of plicae in the lamellae of *D. radiata* is in accordance with those found in *D. exoleta and D. Lupinus* (Atkin, 1937).

The nervous system:

The basic structure of the nervous system of *Dosinia radiata* is so typical of the general type of Bivalvia. However, it shows some differences correlated with certain variations in the mode of life or activities.

The species has two pallial nerve cords, the outer one innervates the peripheral part of the mantle, while the inner one innervates the pallial muscles and pallial sinus. There are no pallial nerve nodes in the pallial cord of the present species but they are found in some other bivalve species as *Modiolus auriculatus* (Aboul-Dahab, 1984).

There are no pallial ayes in the present species but they are present in other bivalve species as *Plicatula gibbosa* and *Spondylus americanus* (Yonge, 1973). According to the latter author, the pallial eyes are concerned with swimming and rapid closure of the shell valves. Being buried under the sand, the present species does not need such photoreceptors. This view is supported by yonge (1973), who reported that the pallial eyes are important only for the free living and swimming forms of Bivalvia.

The visceral ganglia of the present species are fused together in one mass as in some forms of Bivalvia; *Plicatula australis* (Watson, 1930) and *Modiolus auriculatus* (Aboul-Dahab, 1984). The visceral nerve mass is simple in comparison with those in *Pecten and Spondylus goederopus* (Dakin, 1928) and *Psammobia calfornica* (Hilton, 1920b). The complex visceral

ganglionic mass in the previous species is termed by Dakin (1928) as brain and as a nerve controlling center by Yonge (1973). The simple structure of the visceral mass in the present species may be due to the lack of pallial eyes and the mode of life under the sand.

In the present species as in other bivalves as *Pecten maximus* (Dakin, 1928), *Ensis silique* (Graham, 1931) and *Modiolus auriculatus* (Aboul-Dahab, 1984), the pedal ganglia are connected with cerebral ones by pedocerebral cords. On the other hand, in *Spondylus multisetosus* (Yonge, 1973), the connection of pedal ganglia with visceral ones is done through the pedovisceral cords.

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ABREVIATIONS OF PLATES

AAM : Anterior adductor muscle
AP : Anal papilla
APRM: Anterior pelcal retructer muscle.
C : Cerebral commessure
CE : Covering epithelium
CT : Ctenidal teeth
ES : Exhalant siphon
F : Foot (frontal filament)
G : Groove (Ganglia)
GS : Ganglionic sheath
ID : Inner demibranch
TL : Inner lamella

IS : Inhalant siphon
K : Kidney
L : Ligament (Lateral filament)
LF : Letero-frontal
M : Mantle
MU : Mucoid
NC : Nerve cell
OD : Outer demibranch
Ol : Outer lamella
PAM : Posterior adductor muscle
PPRM: Posterior pedal retractor muscle
R : Rectum
RF : Reticular fibers
S : Shell
SBC : Supra branchial chamber
SE : Supra-axial extintion
U : Umbo
VG : Visceral ganglia

EXPLANATION OF FIGURES

Fig. 2.

(A) A camera lucida drawing of the lateral aspects of *Dosinia radiata* after the removal of the right shell valve and the right mantle lobe, showing the anal papilla (AN), exhalant siphon (ES), inner demibranch (ID), inhalant siphon (IS), kidney (K), outer demibranch (OD), rectum (R), suspensory membrane (supra-axial extension) (SE).

(B) A camera lucida drawing for isolated ctenidium to show the length and width of the inner (ID) and outer (OD) demibranchs and the supra-axial extension membrane (SE).

(C) A camera lucida drawing of the ventral aspect of the posterior part of the gills and foot showing inner (ID) and outer (OD), demibranchs, supra-axial extension membrane (SE) and visceral ganglia (VG) with its nerves. (branchial nerve = BN; posterior adductor muscle nerve = PAN siphonal nerve = SN).

(D) A camera lucida drawing of the gill filament shows the different types of cilia; frontal (F); Latera (1) and laterofrontal (1f).

Fig. 3a

(A) A camera lucida drawing of diagrammatic representation of transverse hand section through the anterior region of the

soft parts to show the anterior retractor muscle (ARM), dorsal labial palps (DLP), the inner demibranch (ID), mouth (M), oral groove (OG), and ventral labial palps (VLP).

(B) A camera lucida drawing of diagrammatic representation of transverse hand section through the stomach region (S), showing the crystalline sac (S), inner demibranch (ID), and mid-gut (MG).

(C) A diagrammatic camera lucida drawing of transverse hand section near the posterior region of the stomach to show the inner demibranch (ID), and outer demibranch (OD).

(D) A camera lucida drawing of diagrammatic representation of transverse hand section through the kidney region showing the epibranchial chamber (EBC), kidney (K, rectum (R) and passing through the structure like-ventricle (SV).

Fig. 3b.

Diagrammatic representation of the different types of gills in lamellibranchiata (Types A-G). After Atkins (1937). *Dosinia radiata* represented by type C (2).

Fig. 4.

A camera lucida drawing of a ventral aspect of reconstructed nervous system of *Dosinia radiata* showing its structure. Anterior adductor muscle nerve (AAN), branchial nerve (BN), Cerebral ganglia (CG), cerebropedal (CPC), cerebrovisceral cords (CVC), inner and outer pallial cords (IPC, OPC) respectively, kidney nerve (KN), pedal ganglia (PG), pedal muscle nerve (PN), pallial sinus (SN), posterior adductor muscle nerve (PAN), and visceral ganglia (VG).

EXPLANATION OF PLATES

Pl. 1

(A) A photomicrograph of the outer (OD) and inner (ID) demibranches to show their outer lamellae (OL) and inner lamellae (IL). H.& E. stain x31-35.

(B) A photomicrograph of the outer (OD) and inner (ID) gill demibranchs showing the ventral groove (G). Masson Trichrome stain X 31-35.

(C) A photomicograph of terminal part of the outer demibranch showing the positive PAS contents of the covering epithelium (SE) and reticular fibers (RF) of the basal lamina. PAS methed X125.

(D) A photomicrograph of L. S. upper portion of gill ctenidium to show the super-axial extension (SE) and the suprabranchial chember (SBC). H.&E. stain. X31-35.

(E) A photomicrograph of the terminal part of the outer demibranch showing the mucoid contents (MU) of the epithelial covering. Southgat's muciarmine stain. X200.

P1. 2.

(A) A photomicrograph of sagital section through cerebral ganglia (G) and cerebral commissure (C). H. & E. stain X31-35.

(B) A photomicrograph of T. S. of the pedal ganglia (PG). H & E stian. X31-35.

(C) A photomicrograph of sagital section of the visceral ganglia (VG) to show their general structure. H. & E. stain. X31-35.

(D) A photomicrograph of enlarged part of (B) to show the ganglionic sheath (GS) and nervous cells (NC). H & E stain. X125.

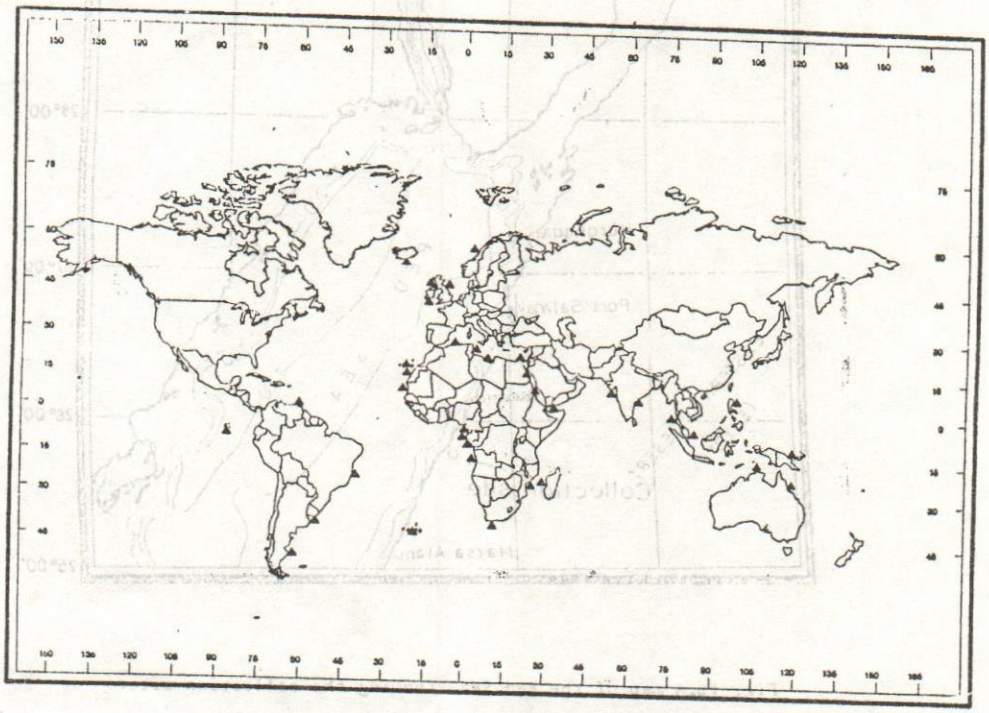

Fig 1 A: A map showing a wide range of the geographical distribution of the genus *Dosinia* in the world.

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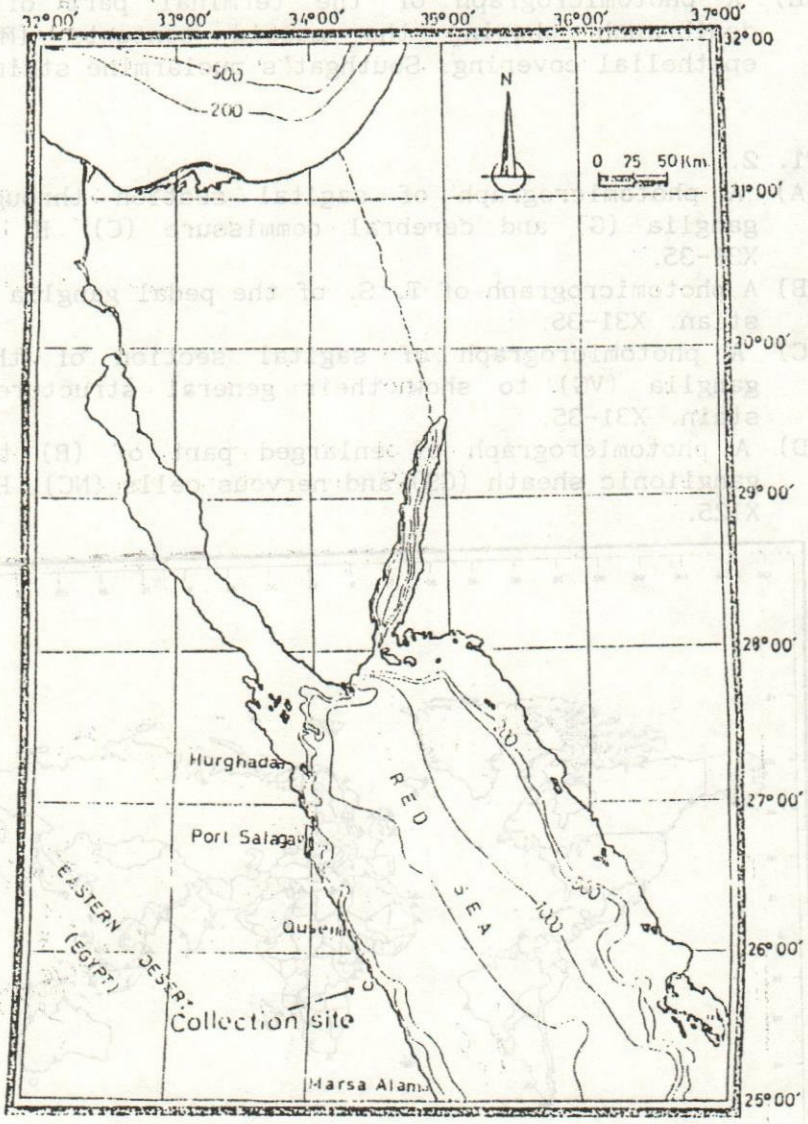
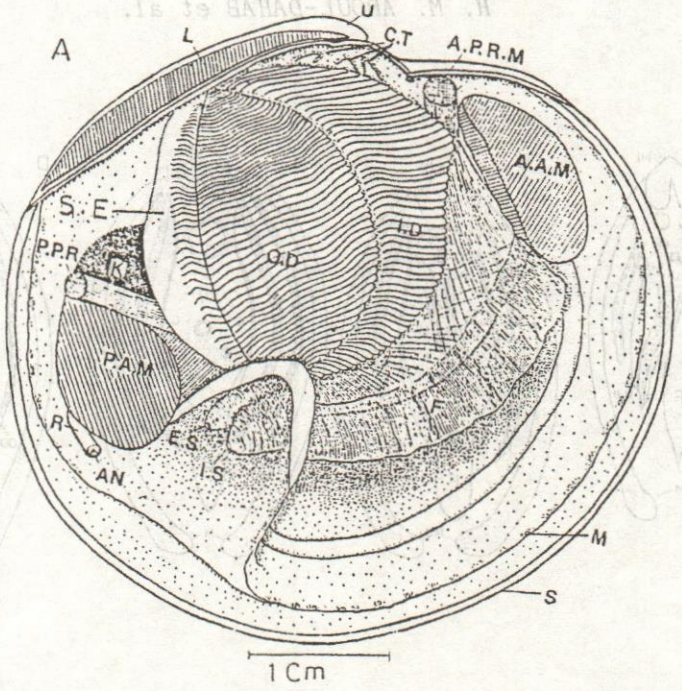


Fig. 1B.A map of the Red Sea, showing the collection site.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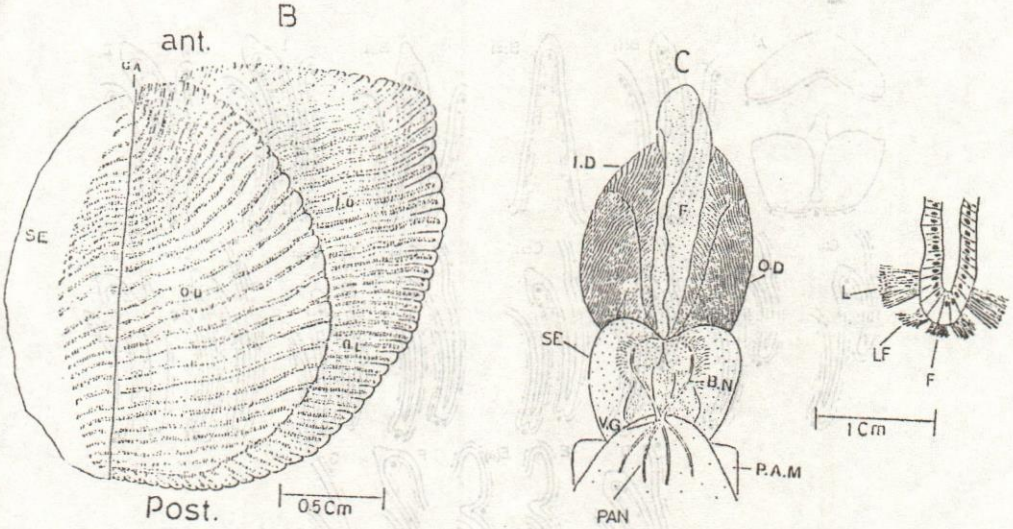
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Fig. 2

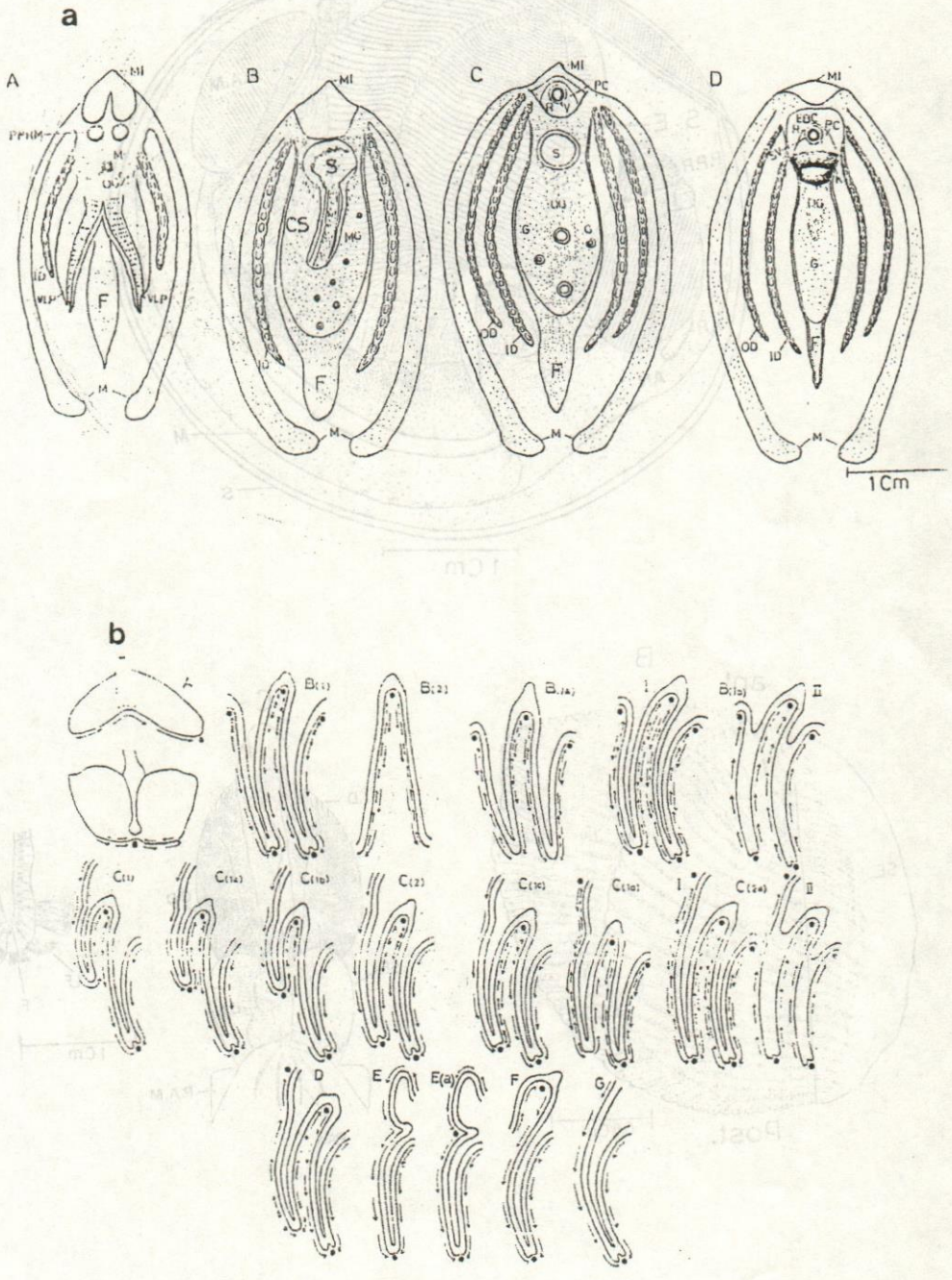

Fig. 3

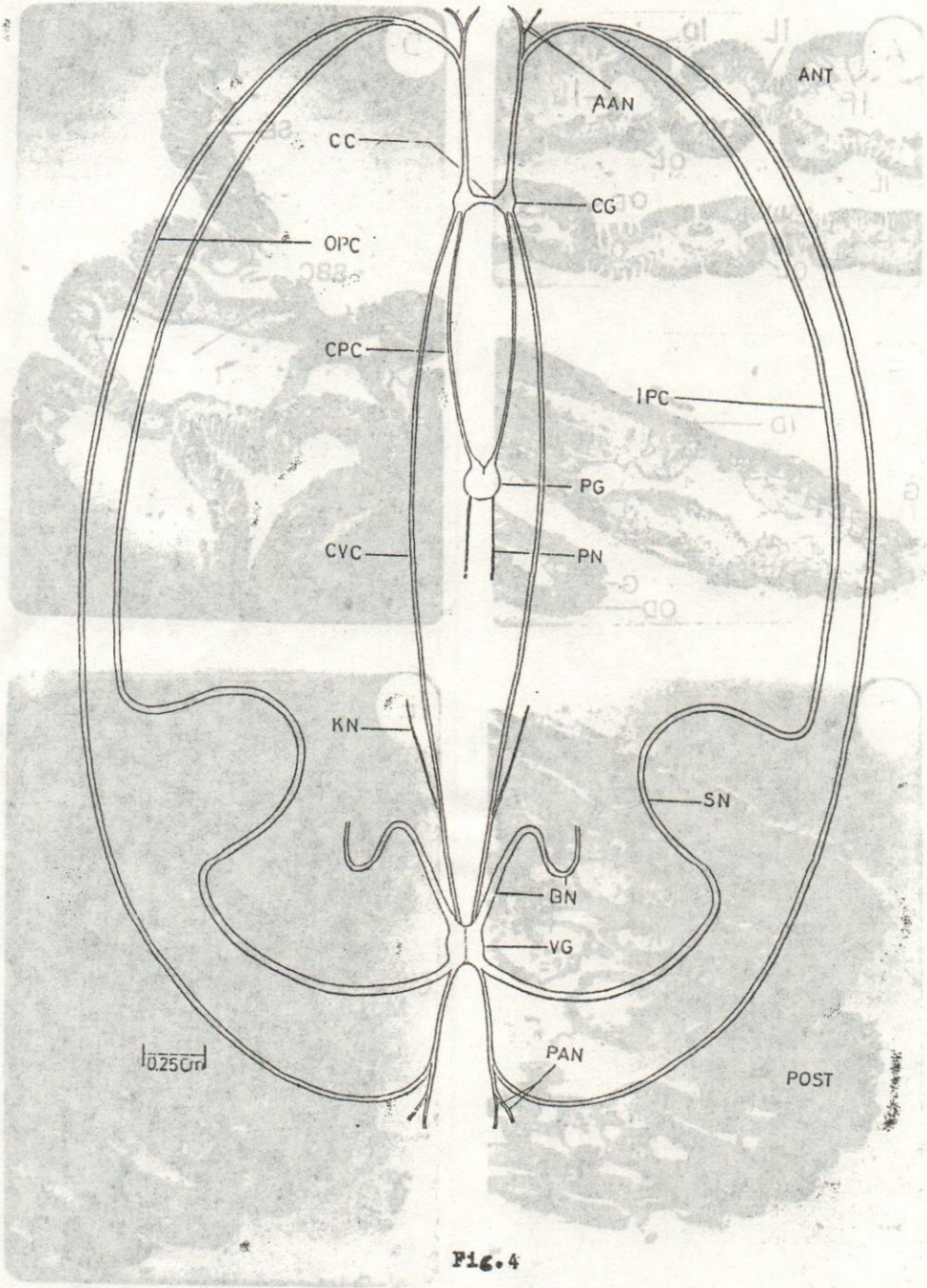

Fig.4

PLATE 1

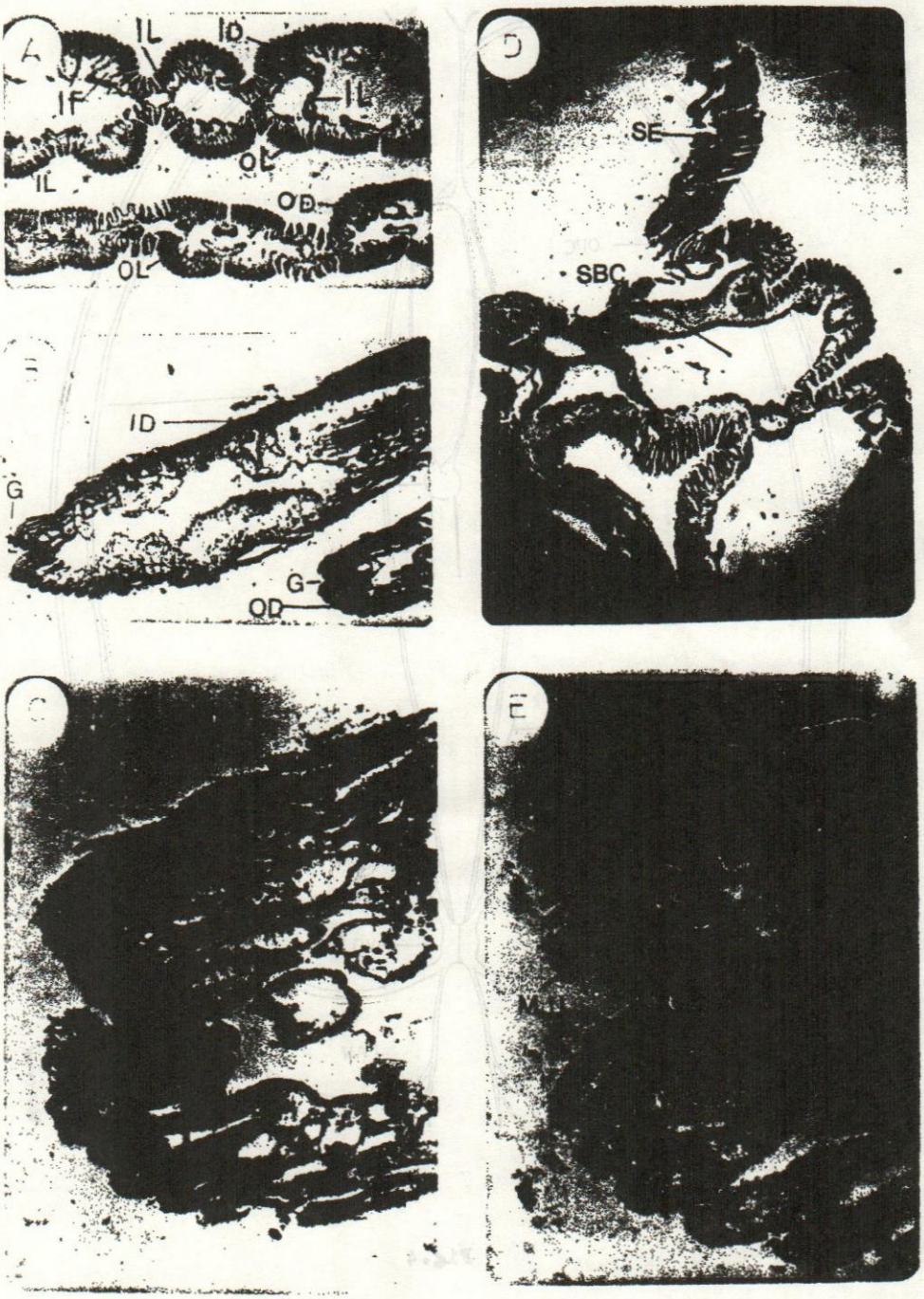

PLATE 2.