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THE DIGESTITIVE SYSTEM OF DOSINIA RADIATA (MOLLUSCA: BIVALVIA) COLLECTED FROM THE RED SEA, EGYPT.

(With 8 Palate & 2 Fig.)

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الجهاز الهضمى لنوع دوزينيا راديانا /رخويات - ذوات المصراعين / جمعت من البحر الاحمر

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اجريت هذه الدراسه على محار دوزينيا راديانا من ذوات المصراعين البحريه التى جمعت من الشاطئ الرملى على شاطئ البحر الاحمر . ولقد بينت الدراسه أن الجهاز الهضمى يتكون من فم يوجد على جانبيه ملماسان شفويان ومرئ قصير ومعده معقدة التركيب (من النوع الخامس) محاطه بغده هاضمه . ويتصل بالمعده معى متوسط ملتحم مع كيس العمود البلورى ثم جزء حر من المعى المتوسط يؤدى الى المستقيم الذى يخترق بطين القلب وتركيب آخر شبيه بالبطين ثم ينتهى بحلمة الشرج . ولقد تبين من الدراسه ان المعده بداخلها ثلاث مجموعات من القنوات الرئيسيه للغده الهاضمه الاولى تتكون من ثمانية قنوات وتفتح فى الردب الايمن للمعده . والثانيه تتكون من ٤ قنوات وتفتح فى الردب الايسر للمعده أما الثالثه فتتكون من ٤ قنوات تفتح فى انخفاض يقع على الجانب الايسر للمعده وبدراسة التركيب المجهرى للمعده وجد أن هناك اتجاهان لمرور الغذاء الأول يحمل المواد الغذائيه السائله والصلبه من المعده الى الحويصلات الهاضمه والاتجاه الآخر يحمل المواد الغير قابله للهضم من الحويصلات الهاضمه الى المعده . ولقد أمكن ملاحظة تميز جدار المعى المتوسط وكيس الغدد البلورى الى خمس مناطق متجاوزه على حسب ارتفاع الخلايا الطلائيه وطول اهدابها . وقد تم الاشاره الى وظيفة كل جزء من أجزاء الجهاز الهضمى كما يتضح من التركيب ونوقشت النتائج مع نظائرها فى الابحاث المنشوره .

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SUMMARY

The marine bivalve *Dosinia radiata* is common in sandy shores of the Red Sea coast. The digestive system of *D. radiata* starts with the mouth which has one pair of labial palps on each side. the mouth leads to cylindrical oesophagus which in turn leads to complicated stomach type (V). Midgut and the combined crystalline sac leave the stomach from its postero-ventral side. The style is secreted inside the style sac and projects into the lumen of the stomach. The style sac leads to a short separate mid-gut which leads to a long coiled rectum. The rectum extends posteriorly penetrating the ventricle and another structure and finally, ends with the anal papilla. The interior architecture of the stomach of *D. radiata,* like other filter feeding bivalves, is very complicated. It shows the characteristic features of stomach type (V) described by Purchon (1960). There are three groups of main ducts opening into the stomach through three embayments. The right caecum of the stomach receives 8 ducts while the left one which is smaller than the right receives 4 ducts. Its left pouch receives 4 ducts. The left and right caeca contain sorting areas while the left pouch is devoid of any one. The microscopic anatomy of the stomach and its digestive diverticula suggests that the digestion is done, as in other filter feeding lamellibranchs, by combination of intra- and extra-cellular processes. Also, there are two ways of circulation which are maintained within the diverticula where, fluid and solid particles being conveyed from the stomach to the tubules while waste materials are conveyed in the opposite direction. The ciliary and muscular activities of the stomach and main ducts may have a main role in the maintenance of the two ways of circulation. According to the height of cells and their cilia, the cross sections of each of the midgut and style sac of *Dosinia radiata* are differentaiated into 5 regions. and cilia.

INTRODUCTION

The genus *Dosinia* is widely spread all over the world (Fig. 1A). It contains large number of species which have large size and interesting patterns of colour. The flesh of the larger sized species are eaten in different parts of the world, while the shell used in industrial purposes. *D. radiata* radiata is common in the sandy shores on the Red Sea coast. Inspite of its abundance in the Red Sea, it has little attention from the malacologists in Egypt.

A few work been carried out on the anatomy of the digestive system of bivalved molluscs. It includes those of Morton (1973 a,b, 1974, 1976, 1979, 1980) on *Laternula truncata* (Lamarck, 1818), *Galeomm* (Paralepida) *Takii, Cleidothaerus maorinus* Finlay, *Polymesoda* (Geloina) *erosa* (Solander, 1786), *Gaimardia* (Neogaimardia) *finlayi, Mantacutona compacta* and *M. olivericea* respectively, that of Hebliny (1976) on *Anodontites trapezeus* (spix) and *A. trapesialis* (Lamarch) and that of Jones (1979) on the anatomy of *Chione cancellata* and some other chionines. Recently, Aboul-Dahab (1983) and Mohamed (1987), studied the digestive system of *Modiolus auriculatus* and *Corpicula sp.* respectively in Egypt.

Many published work is focused on the bivalved stomach and rectum. Among those, Graham (1949) gave a survery of molluscan stomachs; Purchon (1955), made a detailed study for the stomach of many bivalves and has suggested that certain morphological features of the stomach could form the basis of a new classification of Bivalvia; Owen (1953) worked on Glossus humanus and in 1955 he gave a general structure and function of some members of Anisomyaria and Eulamellibranchia in relation to the digestive diverticula; Reid (1965) gave the sturcture and function of 9 species of Bivalvia and Dinamani (1967) gave a detailed survery of the variation in the stomach structure of Bivalvia.

Some those, Pierce (1973) studied the rectum of *Modiolus demissus* and Narain (1975) studied the transpericardial alimentary tract of some bivalves.

Moreover, few studies have been carried out on the digestive system of veneracean bivalves. Among those, Ocklemann (1965) gave detailed studies on the alimentary canal of the venerid bivalve *Turtonia manuta*. Also, Purchon (1960) concluded that the stomach of Veneridae belonges to type V which includes many other families of Eulamellibranchia.

MATERIAL AND METHODS

The specimens of *Dosinia radiata* used in the present study were collected from a single site on the Red Sea Coast. This site is a sandy shore located at 45 km south of Quesir City (26° 30 N, 34°40 E), (Fig. 1B). Specimens were collected from the field, at the time of low tide about 0.0-0.5 meter deep. Collection was done by hand's finger to set underneath the mussel, pick it up with hand and put in a plastic container containing 10% aqueous formalin. The specimens were taken to the laboratory for anatomical studies. Measurements of the digestive system were done using calibrated ocular microscope. Drawings were done with help of a camera lucida.

Paraffin sections were made by fixation of some parts or organs of the alive specimens in a Bouin's solution for 24 hours. Fixed materials were passed to wash in 30 and 50% alcoholic solution then passed to a graded series of alcohol from 70 to 100%. They were cleared in xylene, then embedded in paraffin wax. Sectioning was made at 6-7um thick. Staining was carried out using haematoxylin and Eosin combination. 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 carbohydrates respectively.

RESULTS

Samples of *D. radiata* are handsome with strong and rounded shells (Pl. 1, A). By removal of the shell, the mantle lobes covering the soft parts were exposed. By removal of mantle lobes, follicles of the gonad, digestive gland and most of the digestive system were exposed (Pl. 1, B, C).

Digestive system of *Dosinia radiata* consists of the following main parts (Fig. 2):

A - The mouth and the labial palps.
B - The oesophagus.
C - The stomach and the digestive diverticula.
D - The style sac and midgut.
E - The separate midgut
F - The rectum.

A - the mouth and the labial palps:

The mouth of *Dosinia radiata,* lies at the middle of the anteroventral side of the visceral mass which is situated

behind the anterior adductor muscle. The mouth opening, during unuse, is rounded in shape and surrounded by some of radial ridges (Fig. 2, C).

On the two sides of the mouth opening, there are two pairs of labial palps, one is front or dorsal to the mouth and the second is behind or ventral to it (Fig. 2, A, B). The first is slightly longer being about 8.47 while the seconed is 7.85 mm long. The inner suface of each palp is characterized by an outer smooth unridged portion and an inner ridged one. The ridged portion consists of alternative transverse ridges and grooves (Fig. 2, A, B).

Histological studies show that each labial palp consists of folded and smooth sides enclosing a core of connective tissue structure (Pl. 2, A-D). The folded side has a simple ciliated columnar epithelium along its ridges and grooves while the smooth side has a low cuboidal covering epithelial layer (Pl. 2, A-D). The folded side also has a brush bordered terminal edge, showing its affinity to basiic stains and forming a continuous sheath beneath the cilia (Pl. 2, A). Fine scattered nasohpilic and homogenated cytoplasmic granules appear within these cells. Also, the cells show positive reactions towards the PAS and mucoid detection (PL. 2, C, D), while the low cuboidal cells show high affinity towards the PAS reaction (PL. 2, C)>. The epithelial covering of the two sides is based on a fibrous basal lamina enriched with collagenous and reticular fibers (Pl. 2, B, C). The connective tissue core contains scattered bundles of less organized muscle fibers, blood sinuses, collagenous and reticular fibers (Pl. 2, B, C). Such structures of the labial palps serve their movement and collecting the food particles and push them into the mouth.

B - The oesophagus:

The mouth opening leads directly into a long oesophagus being about 3.94 mm long. The oesophagus passes upwards and backwards to open at the anteroventral margin of the stomach (Fig. 2, D, F). In cross section, the oesophagus is oval shaped, being about 0.63 and 0.4 mm in maximum and minimum values of axes respectively.

The histological sections show that the oesophageal wall consists of three layers; mucosa, thin submucosa and muscularis (PL. 3, A-D). The mucosal lining is composed of simple ciliated columnar cells with few mucus secreting cells (PL. 3, C, D). The muous cells are heavily stained with PAS, while the apical portions of the structural cells are faintly stained (PL. 3, D). The mucosal cells rest on a basal fibrous lamina which is containing collagenous and reticular fibers (PL. 3, B, C). The

submucosa is so thin that it can be only seen in the small folds of the basal lamina (PL. 3, B).

The muscular layer is composed mainly of circular muscle fibers (PL. 3, B). Such structure of the oesophagus shows that it conveys food to the stomach by help of cilliary, muscular and secretory activities.

C - The stomach and the digestive diverticula:

The stomach of *Dosinia radiata* is a large sac-like structure situated nearly in the mid-dorsal location of the visceral mass below the region of the umbo (PL. 1, B, C). It is surrounded anterioly with follicles or acini of the digestive diverticula. The gonadal follicles intermingle with the digestive diverticula and concentrate mainly around the posterior half of the stomach. After removal of the follicles of the digestive gland and gonadal tissues, the stomach becomes exposed (Fig. 2, D, F, G). The naked stomach appears, nearly, globular shaped with well developed dorsal hood which projects upwards from the stomach roof and is curved towards the left side (Fig. 2, G). The oesophagus enters the stomach on its anterior ventral margin, while the combined style sac and midgut passes directly downwards into the visceral mass from the posterior floor of the stomach (Fig. 2, D; PL. 1, B, C). The exposed outer surface of the stomach shows three groups of main ducts, coming from the digestive diverticula and entering the stomach throughout the right caecum, left caecum and left pouch (Fig. 2, F, G).

In one specimen the roof of the stomach was removed (Fig. 3, A), and in anther one an incision from mid-dorsal of the stomach was made (Fig. 3, C). So, the internal architecture of the stomach could be differentiated into some different important structures. The posterior left wall of the stomach is covered with the gastric shield which is a transparent and saddle shaped structure (PL. 4, B; Fig. 3, D). It has two flares which invest the mouth of the dorsal hood. It is about 5.63 x 3.56 mm in maximum length and width respectively. The gastric shield protects the inner wall of the stomach against the rotation of the crystalline style. At the anterior floor of the right side of the stomach there is a small pocket-like structure known as a right caecum (PL. 4, A; Fig. 3, C). The interior of the right caecum contains a storting area and receives 8 main ducts of the digestive diverticula (PL. 4, A; Fig. 2, F). Four of them anter the right caecum from its dorsal side while the other four ducts enter through its ventral side. Also, the anterior floor of the left side of the stomach

contains a pocket-like struture called the left caecum which is smaller than the corresponding right one (PL. 4, A; Fig. 3, C). Its interior surface contains a sorting area and receives four main ducts of the digestive diverticula (Fig. 2, G). On the left anterior wall of the stomach close to the mouth of the left caecum, there is a little depression known as the left pouch which receives 4 ducts from the digestive diverticula (PL. 4, A; Fig. 3, C).

The posterior floor of the stomach receives the midgut and crystalline sac. A major typhlosole emerges out from the midgut and passes anteriorly on the floor of the stomach. It is accompanied on its right side by the small depression called the intestinal groove. The major typhlosole and the intestinal groove pass forward on the floor of the stomach, very close to its right wall and enter the right caeum. They emerge from the right caecum, cross the anterior floor of the stomach fromach from right to left and enter the left caecum (Fig. 3, A, C). Owen (1955) reported that the major typhlosole in the stomach of lammellibranchiates is important for isolation of the rejectory currents of the intestinal groove from the main stomach cavity.

A minor typhlosole emerges from the midgut into the stomach and accompanies the intestinal groove from its right side. It passes forwards for a short distance and then terminates on the right wall of the stomach between the orifice of the mid-gut and orifice of the right caecum (Fig. 3, A, C).

The anterior part of the floor of the stomach contains a well developed area with fine ridges and grooves forming what is known as sorting area one (SA1). This area extends on the right wall of the stomach and passes posteriorly to end close to the orifice of the mid-gut forming the sorting area two (SA2). It is worth mentioning that, there is a third sorting area (SA3) on the roof of the stomach (Fig. 3, B).

The histological and histtochemical studies of the stomach wall show that, it is lined with a simple ciliated columnar epithelium. The epithelium rests on a basal fibrous lamina formed mainly of collagenous and reticular fibers (PL. 4, C). The epithelial cells show positive reactions for PAS, mucoid detection and glycogen (PL. 4, C, D). Such structure of the stomach leads to the assumption that its wall can exert certain muscular contractions which together with the cilia can produce a food current and direct it either to the posterior part of the stomach, or to intestinal lumen or to the digestive diverticula ducts according to the size and nature of the food particles.

Digestive diverticula :

The digestive diverticula of *D. radiata* consists of a huge number of compact groups of dark greenish blind ending tubules or acini, surrounding most of the oesophagus and the stomach. They communicate with a system of very short secondary ducts leading to a smaller number of main ducts which in turn open into the stomach (pL. 5, A).

In sections each tubule has an oval elongated outline, measuring about 80 x 93 um in maximum diameters. It consists of a thin wall and a relatively wide lumen. It is important to note that, the outer surface of the tubules contains some amoebocytes which may be partly used for the elimination of the waste products and partly for the distribution of absorbed soluble matter. The simple columnar epithelial cells can be differentiated into two types; the first is formed of short oval or pyramidal darkly stained cells with large oval central nuclei positively stained for PAS and mucoid detections (PL. 5, C, D). These cells may secrete digestive secretions and mucus. This type of cells is smaller in number and varies in height, ranging from 5 to 8 um in length. Some of these cells form groups, laying between large vacuolated cells which meet above them, and shut them from the lumen of the tubules.

The second consists of long lightly stained cells containing numerous vacuoles and basal ovoid small nuclei which may be used for absorption of food. This type of cells in larger in number than that of the first one and contains a large number of vacuoles in its cytoplasm. They vary in height which ranges from 8 to 13 um. The variation of the second group of cells leads to the irregular and triangular lumen of the tubules with some depressions and elvations (PL. 5, D). The same observation has been recorded by Yonge (1926) and Owen (1955) for tubules of many other lamellibranchs.

Short seconday ducts connect the blined tubules with the main ducts. In cross section, each secondary duct is roughly rounded in shape, about 75 um in greatest diameter. Histological sections show that each secondary duct has a well defined epithelial lining, consisting of low columnar epithelial cells and outer thinn basal fibrous laminal layer. The columnar cells have lightly stained nuclei and apical portions with heavily stained brush borders (PL. 5, C). These cells may aid in food absorption.

The wall of the main ducts has a simple epithelial lining, resting on a fibrous basal lamina formed of collagenous, reticular and elastic fibers (PL. 5, B, C, D). Such structure

of the main duct supports the view that it may permit two ways of food circulation, an inhalant current carrying the suitable material from the stomach to the digestive diverticula and an exhalant one, created by the cilia, which can convey materials as enzymes and unwanted matter in the opposite direction to the stomach.

It is know by most malacologists that, digestion in lamellibranchiates is a combination of intracellular and extracellular processes. According to *Yonge (1926)*, the crystalline style is a source of extracellular carbohydrates. He reported also that the acini of the digestive diverticula have the function of absorption of soluble substances and the ingestion and intracellular digestion of the fine particles, partially broken by the amoebocytes. So, the fluid and fine particles pass from the stomach to the digestive diverticula, while waste materials are conveyed in the opposite direction from digestive diverticula to the stomach. The prevoius description of the structure of the stomach and the digestive gland of *D. radiata* agrees with their function for digestion and absorption of food.

D- The style sac and midgut :

From the posterior floor of the stomach a combined mid-gut and style sac passes downwards into the visceral mass. It extends to the upper border of the foot, then bends upwards to give separate midgut which leads to the coiled rectum (Fig. 2, D). A hayline rod, termed as the crystalline style, projects from the crystalline sac into the lumen of the stomach. Kato & Kubonura (1954) reported that the style is secreted from the style sac, and according to Yonge (1949), it pushe forward slowly and dissolves in less acid medium of the stomach.

Cross sactions throughout the combined mid-gut and style sac show that the midgut lies at the floor of the style sac (Fig. 3, E). Also, histological sections show that the sac has a distinguishably wider lumen than the midgut. The crystalline sac is oval shaped and laterally compressed, while the midgut has an inverted L-shaped lumen (PL. 6, A; Fig. 3, E).

According to the variations in the height of the lining epithelium and its cilia, the wall of the combined style sac and midgut can be differentiated into five distinct adjacent regions along their periphery:

1 - The first region A:

Region A of crystalline sac has a compact ciliated columnar epthelial lining with elongated nuclei. The cells of this region has a highest length ranging from 104 to 169 um and

the cilia are about 18 um long (PL. 6, A, C; Fig. 3, E).

2 - The second region B:

The cells of this region line the greatest part of the wall of the style sac. They are ciliated columnar, varying from 54 to 106 um in length, with oval nuclei and cilia are about 15 um long. They are glandular or vacuolated, indieating that this region may be responsible for the secretion of the matrix of the crystalline style and facilitate its rotation during functioning by the cilia (PL. 6, A, D; Fig. 3, E).

3 - The third region C:

This type of cells lines small area of the wall of the midgut. The cells are ciliated columnar varying in lenght from 46 to 78 um with oval and basally located nuclei. The cilia are few and longer than those of other types; being from 26 to 31 um in lenght (PL. 6, A, B; Fig. 3, E).

4 - The fourth region D:

This type of cells occupies the floor of the midgut. The wall of this region is characterized by short alternative ridges and grooves. The ridges have apical cells measuring about 20 um in lenght with distinct cilia being about 10 um in length. The grooves contain basal cells measuring about 13 um in length with cilia about 7 um long (PL 6, A, B; Fig. 3, E). Some of these cells are darkly stained with PAS and others are vacuolated indicating their secretory function.

5 - The fifth region E:

The cells of this region lines the rest of the wall of the midgut and they are ciliated columnar ranging from 44 to 62 um in length. They have heavy cilia ranging from 13 to 15 um 1 long (PL. 6, A, C; Fig. 3, E). Some of these cell are darkly stained with PAS indicating their secetory function in comparison with the ramaining lightly and homogeously stained cells which may be absorptive in function.

The epithelial lining of the crystalline sac and midgut rests on a basal lamina containing collagenous and reticular fibers (PL. 7, A-D).

The core of the style sac contains the crystalline style PL. 6, A). In fresh specimens, the style appears as a hayline rounded rod and its anterior tip projects into the stomach.

E- The separate Midgat :

The separate midgut joins the conjoined crystalline sac and midgut from their posterior end and is directed upwards to join the coiled rectum (Fig. 2, D). Cross section in the separate midgut shows that it has a C-shaped lumen with a large typhlosole (PL. 8, A, C). Histological and histochemical observations reveal that, its wall consists of a ciliated columnar epithelial lining. The lining cells rest on a fibrous basal lamina containing reticular fibers (PL. 8, C). Some of the previous cells are slightly PAS positively reacted. Such structure of the mid-gut supports the assumption that it helps in absorbing and consolidating the rejected particles towards the rectum by the action of their cilia.

F - the rectum:

The rectum begins when it joins the separate midgut and coils on itself to give a coiled part, which passes posteriorly downwards and upwards, to extend transversely for a short distance alongside the posterior margin of the stomach. Then it passes poseriorly and penetrates the ventricle. The rectum emrges from the ventricle for a short distance before penetrating an unknown structure like-ventricle, and continues posteriorly to bend downwards over the posterior adductor muscle and end with an anal papilla (Fig. 2, D, E). Histological and hisochemical studies show that the rectal wall has an epithelial lining of ciliated columnar cells based on a fibrous membrane (PL. 8, B).

The wall of the anal papilla is folded forming ridges and grooves. The ridges are found in simple and multiple forms (PL. 8, D, E). Cross section through the anal papilla shows that, it has the basic structure of the rectal wall. Such stucture of the rectal wall and anal papilla is chiefly suitable for collection consolidation and rejecting of indigestible materials.

DISCUSSION

Generally, the gross anatomy and histology of the digestive system of *Dosinia radiata* is similar to that of other bivalve species. The present species has certain common features in accordance with those of other filter feeding bivalves, specially eulamellibranchs which were mentioned by Purchon (1960). These charaters are the cylindrical oesophagus, crystalline style secreted within the style sac and projecting into the lumen of the stomach and the style sac combined with the mid-gut.

The labial palp of *D. radiata* are large as in some bivalved species; *Musculista sentausia* (Morton, 1974), Anodontites trapesialis and *A. trapezeas* (Hebling, 1976) and *Limnoperna fortunei* (Morton, 1973). Yonge (1949) reported that large labial palps are common among burrowing bivalves, in which fine unwanted materials enter to the mantle cavity through the suction action of the inhalant siphon. So, large labial palps have an efficient separation that prevents the access of unwanted materials into the mouth. The histological and histochemical studies of the oesophagus of the present species show that the food particles can pass through it into the stomach by ciliary, muscular and secretory activities and not only by ciliary activity as recorded by Purchon (1977).

The interior architecture of the stomach of *D. radiata* like that of any of other filter feeding bivalves is very complicated (Graham, 1949; Purchon, 1957, 1960, 1977; Reid, 1965; Dinamani, 1967). It shows characteristic features of stomach type V, described by Purchon (1960). These characters are the following: the major typhlosole with the intestinal groove on its right side emerges from the midgut to enter the right caecum of the stomach and emarges from it to pass transversely from right to left and enter the left caecum, the minor typhlosole terminates on the right wall of the stomach, the dorsal hood is well developed, combined mid-gut and style sac leave the stomach from its posterior floor and the oesophagus joins the stomach at its anterior margin.

The present investigation reveals that *D. radiata* possesses some anatomical characters of the digestive system in accordance with those mentioned by Purchon (1960, 1977) for the venerid bivalves, specially *D. lumpinus*.

There are three groups of main ducts opening into the stomach through three embayments. the right caecum receives 8 ducts while the left one which is smaller than the right receives 4 ducts and the left pouch receives 4 ducts. The interior of the left and right caeca contain sorting areas. Similar finding was given by Purchon (1960) for venerid bivalve *Gafrarium minimum* which has only 7 main ducts opening into the right caecum.

The stomach wall and the sorting areas of the present clam are lined with a ciliated epithelium. Cilia of the stomach wall may create a current of food particles towards the sorting areas which in turn remove heavy particles and reject them via the intestinal groove, while the fine particles in suspension of the gastric fluid are carried into the mouth of the mid-gut.

Similar interpretation was given by Reid (1965) for the polysyringian stomach.

The microscopic anatomy of the stomach and digestive diverticula of the present material elucidates that digestion is carried out as in other filter feeding lamellibranchs, by combination of intra- and extra-cellular processes. The results of this work coincides with the findings of Owen (1955) who reported that the digestion of food particles occurred within the digestive cells of the digestive diverticula, which digest small particles, absorb soluble matter and accumlate unwanted materials at their distal ands to be discharged via the stomach to the midgut. Also, this study agrees with that of Owen (1955), who suggested that two ways of circulation must be maintained within the diverticula; fluid and solid particles being conveyed from the stomach to the tubules while waste materials are pushed in the opposite direction. The ciliary and muscular activities of the stomach and main ducts of the digestive diverticula may have a main role in the maintenance of the two ways of circulation. This view supported by Yonge (1973) who reported that cilia maintain a continuous circulation within the diverticula, while Graham (1949), Owen (1953) and Purchon (1955) suggested that the muscular activity plays a part in circulation within the gut of lamellibranchs, especially in the stomach and digestive diverticula.

The crystalline style in the present species as in other bivalved molluscs is secreted from the crystaline sac (Kato & Kubonura, 1954). According to Purchon (1977), the srystalline style performs a number of functions; it helps for dragging food particles into the stomach. It reduces the size of the food particles and seprates the different contents of the food diet by rubbing the contents of the stomach against the gastric shield; it liberates some enzymes which initiate the extracellular digestion of the stomach.

The style sac and midgut of the present species are conjoined as in many of eulamellibranchs such as *Cleidothaerus maorianus* (Morton, 1974), *Polynesoda erosa* (Morton, 1976), *Anodontites trapezeus* and *A. trapesialis* (Hebling, 1979) and Gaimardia finlagi (Morthon, 1979). Morton (1976) reported that the separate style sac in Eulamellibranchia could be derived from the conjoined one. Also, in primive bivalves, he considered that the style is secreted within the midgut and later achieving functional separation from the midgut by development of parallel tube housing the style and separated from the midgut by a typhlosole as in *Mytilus galloprovincialis* (Giusti, 1971), *Sphaerium notatum* (Monk, 1928) *and Grassostrea gigas* (Bernard, 1973). These considerations are similar with

those deduced in the present investigation. In other bivalves, he also considered that physical and functional separation of the style sac has been achieved in *Galeomma takii* (Morton, 1973b).

According to the height of cells and their cilia in the cross sections, the midgut and style sac of the present material can be differentiated into five regions (A, B, C, D, E). The lining of the style sac in *Corpicula sp.* (Mohamed, 1987) was differentiated into four regions (A, B, C, D). Kato & Kubomura (1954) and Morton (1976), recognized three regions A, B, and C in alive specimens as well as preserved.

The section through the separated midgut shows that it has a large typhlosole, and a ciliated columnar epithelial lining resting on a basal lamina. Such structure of the midgut reveals its function, as viewed by Owen (1955) and Purchon (1977) in other bivalves, to be collection and consolidation of the rejected particles.

The route of rectum in the present species as in most bivalves, is to be passed through the ventricle. In few other bivalves, the rectum passes above the ventricle and kidney as in *Pandora inaequivalvis* and *P. pinna* (Allen, 1954) and *Cleidothaerus albidus* (Morton, 1974).

The rectal wall of the present species is composed of a ciliated epithelial lining with mucus secreting cells resting on a basal lamina formed of a connective tissue supplied with circular muscle fibers. Such structure of the rectal wall supports its function for consolidation and propulsion of faecal matter.

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ABREVIATIONS

AA : Anterior adductor muscle
AP : Anal-papilla.
AZ : Apical zone
BL : Basal lamina.
C : Cuboidal cells
CE : Covering epithelium.

CF : Collagenous fibers
CS : Crystalline style (sac)
DH : Dorsal hood
E : Enhalant siphon
EP : Epithelial lining
GL : Glycogen
I : Exhalant siphon
IG : Intestinal groove
M : Mouth
MC : Mucus secreting cells).
MG : Mid-gut
MU : Mascularis
O : Oesophagus.
OG : Oral groove
PA : Posterior adductor muscle
R : Rectum.
RD : Ridges
S : Stomach
SA2: Sorting area 2
SD : Secondary duct
SS : Crystalline style
V : Ventricle.

CM : Ciliated mucosa.
CT : Connective tissue.
DLP: Dorsal labial palp.
EF : Elastic fibers.
g : PAS positive granules.
GS : Gastric sheild.
LC : Left caecum.
K : Kidney.
MB : Muscle bundles.
MD : Main duct.
MT : Major tephlosole.
MY : Minor typholosole.
R : Rectum.
PC : Pyramidal cells.
RC : Right caecum.
RF : Reticular fibers.
SA1: Sorting area 1.
SA3: Sorting area 3
SM : Submucosa.
SV : Sturcture like ventricle.

EXPLANATION OF FIGURES

Fig. 2.

(A) A camera lucida drawing of the labial palps in normal position to show the dorsal labial palp (DLP) and the ventral labial palp (VLP).
(B) A camera lucida drawing of the labial palp in situ after turn over the dorsal labial palp, showing the mouth opening (M) and the oral groove (OG).
(C) A camera lucida drawing of the magnified part of (B) showing the mouth opening (M), oral groove (OG), ridges (R) around the mouth.
(D) A camera lucida drwing of separate alimentary canal to show mouth (M), oesophagus (O), stomach (S), dorsal hood (DH), crystalline sac (CS), midgut (MG), rectum (R) and anal papilla (AP).
(E) A camera lucida drawing of the anal papilla (AP).
(F) A camera lucida drawing of the right side of an exposed stomach after removal of the digestive diverticula and gonad. (CS= crystalline sac; DH= dorsal hood; MD= main duct; O= oesophagus).

(G) A camera lucida drawing of the left side of the exposed stomach after removal of the digestive diverticula and gonad. (CS=crystalline sac; DH= dorsal hood; MD= main duet; O= oesophagus).

Fig. 3.

(A) A camera lucida drawing illustrating the isolated stomach after the removal of its roof. (IG= intestinal groove; MG= mid-gut; MT= major typhlosol; MY= minor typhlosol; SA1= sorting area of the floor of the dorsal hood; SA2= sorting area of the right side wall; SS= style sac).
(B) A camera lucida drawing illustrating the interior of the dorsal hood to show sorting area (SA3) on it.
(C) A camera lucida drawing of the interior of the stomach after its opening by a middorsal incision showing left caecum (LC), left pouch (LP), right caecum (RC), sorting area (SA1), sorting area (SA2) and sorting area of the stomach roof (SA3).
(D) A camera lucida drawing of the gastric shield (GS).
(E) A diagrammatic representation of the conjoined style sac and midgut to show its different regions A, B, C, D, and E.

EXPLANATION OF PLATES

PL. 1.

(A) A photomicrograph of *Dosinia radiata* (Left side) showing the external morphology and the shell characters.
(B) A photomicrograph of the lateral aspect, after the removal of the gonad and digestive gland to show the digestive system in situe and siphons.
SV= structure like ventricle; ES= exhalant siphon; IS= inhalant siphon;
V= ventricle; S= stomach; CS= crystalline sac).
(C) A magnifaied part from (B)

PL. 2.

(A) A photomicrograph of T. S. of the labial palp showing its general structure with the folded and the smooth sides of the covering epithelium (CE). H & E stain. X 125.
(B) A photomicrograph of an enlarged portion of (A) to show the collagenous fibers (CF) of the basal lamina. The collagenous fibers (CF) diffused throughout the connective tissue bulk (CT). The basophilic apical epithelial zone and muscle bundles (MB) are also shown.
Masson Trichrome stain. X 125.

(C) A photomicrograph of an enlarged part of (A) to show the PAS positive contents of the covering epithelium (CE) and the reticular fibers (RF) of the basal lamina. PAS method. X 125.

(D) A photomicrograph of an enlarged portion of (A) showing the mucoid contents (MC) of the epithelial layer. Southgat's mucicarmine stain. X200.

PL. 3.

(A) A photomicrograph of T. S. of oesophagus showing general structure.
(CM= ciliated mucosa; MU= muscularis; SM= submucosa). H & E stain. X200.

(B) A photomicrograph of T. S. of oesophagus showing the collagenous fibers (CF) of the basal lamina of the lining mucosa (M), the thin submucosa (SM) in the folded regions of the basal lamina and muscularis (MU). Masson Trichrome stain. x 125.

(C) a photomicrograph of oesophagus to show the PAS positive substances of the lining epithelium cells and the reticular fibers (RF) of the basal lamina and mucus secreting cells (MC). PAS method. 125.

(D) a photomicrograph of enlarged portion of (C) showing the mucous secreting saccular cells (MC). PAS method. X 500.

PL. 4.

(A) A photomicrograph of section to show the right (RC), left caeca (LC), and oesophagus (O). H & E stain. X 31.35.

(B) A photomicrograph of section of stomach to show the crystaline style (CS) and the gastric shield (GS) lining the left side of it. H & E stain. X 31.35.

(C) A photomicrograph of (A) to show the reticular fibers (RF) of the basement membrane and the heavily stained apical zone (AZ) of the lining epithilium. PAS stain. X125.

(D) A photomicrograph of (A) to show the glycogen like substances (GL) which appear in the form of small granules. Best's carmine stain. X200.

PL. 5.

(A) A photomirograph of a section of the digestive gland to show its general structure, digestive tubules or follicles (F), secondary ducts (SD), and main duct (MD). H & E stain. X 200.

(B) A photomicrograph of T. S. of the digestive gland to show the collagenous fibers (CF) of the basal lamina of the digestive follicles, heavily stained pyramidal cells (PC) of the digestive tubules (F). Masson Trichrome method. X 200.

(C) A photomicrograph of a section the digestive gland to show the PAS positive staining reticular fibers (RF) of the basal lamina of the digestive tubules, PAS positive granules (G) scattered throughout the interfollicular connective tissue, deeply stained pyramidal cells (PC) of the digestive tubules and a lightly stained brush borders of the secondary ducts (SD). PAS reaction. X 200.

(D) A photomicrograph of an enlarged portion of a section of the digestive gland to show the elastic fibers (EF) of the basal lamina of the digestive tubules. Orcein stain. X 500.

PL. 6.

(A) A photomicrograph of T.S. of the conjoined srystalline sac and midgut to show the different part of its wall (A-E) and a part of crystalline style (CS). H. & E. stain. X 31.35.

(B) Enlarged portion of (A) showing the regions (C & D). H & E stain. X 200.

(C) A photomicrograph of enlarged portion of (A) to show the regions (A & E). H & E stain. X 200.

(D) A photomicrograph of enlarged portion of (A) to show the region (B). H & E stain. X 200.

PL. 7.

(A) A photomicrograph of region (B) to show reticular fibers (RF) and normal staining affinity of the structural cells. PAS stain. X 200.

(B) A photomicrograph of region (C) to show the lightey stained club cells (C) and the heavily stained apical zone (AZ) of the structural cells. PAS stain. X 200.

(C) A photomicrograph of regions (D & E) to illustrate the heavily stained mucous secreting cells (MC). Southgat's mucicarmine stain. X 200.

(D) A photomicrograph of region (A) showing the heavily stained apical zone (AZ). PAS stain. X 200.

PL. 8.

(A) A photomicrograph of separate midgut to show the lining epithelium of the wall (EP). H & E stain. 31.35.

(B) A photomicrograph of enlarged portion of T. S. of the rectum inside the ventricle sowing its lining ciliated epithelium (EP) and underlying thick basal lamina (BL). H & E stain. X 200.

(C) A photomicrograph of enlarged portion of (A) to show the reticular fibers (RF) of the basal lamina and the heavily stained apical zone (AZ). PAS stain. X 200.

(D) A photomicrograph of L. S. of the posterior region of the rectum (R) conjoined with the anal papilla (AP). H & E stain. X 13.35.

(E) A photomicrograph of enlarged portion of (D) to show a simple and multple folds of the anal papilla (AP). H & E stain. X 200.

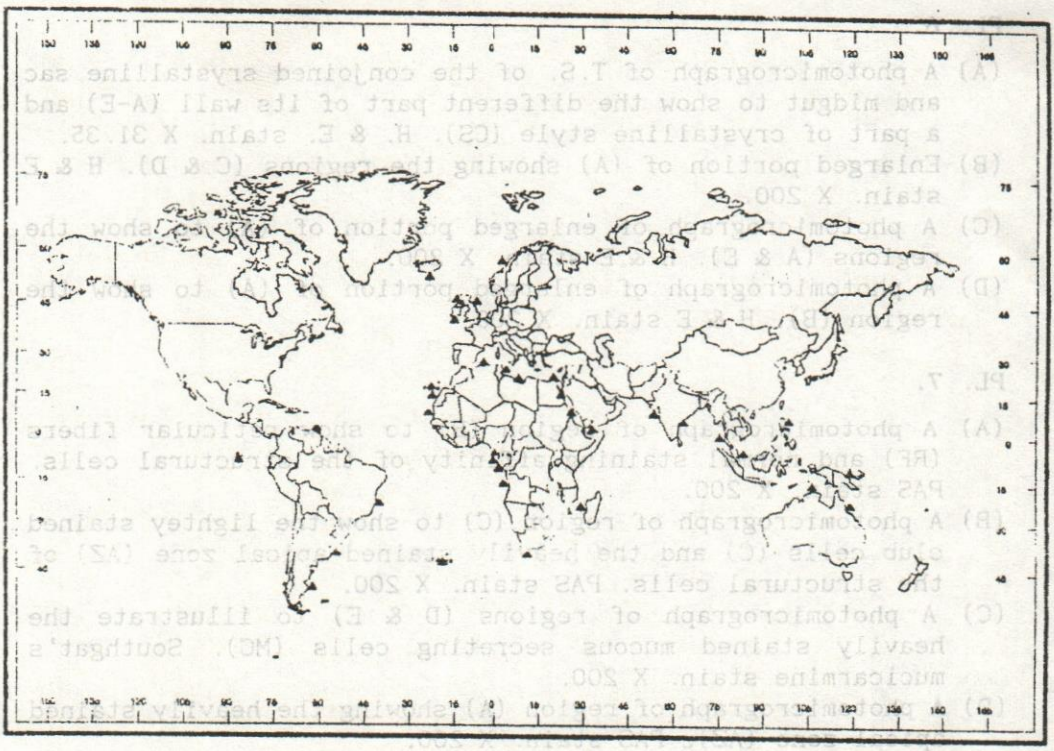

Fig 1 A. A map showing a wide range of the geographical distribution of the genus *Dosinia* in the world.

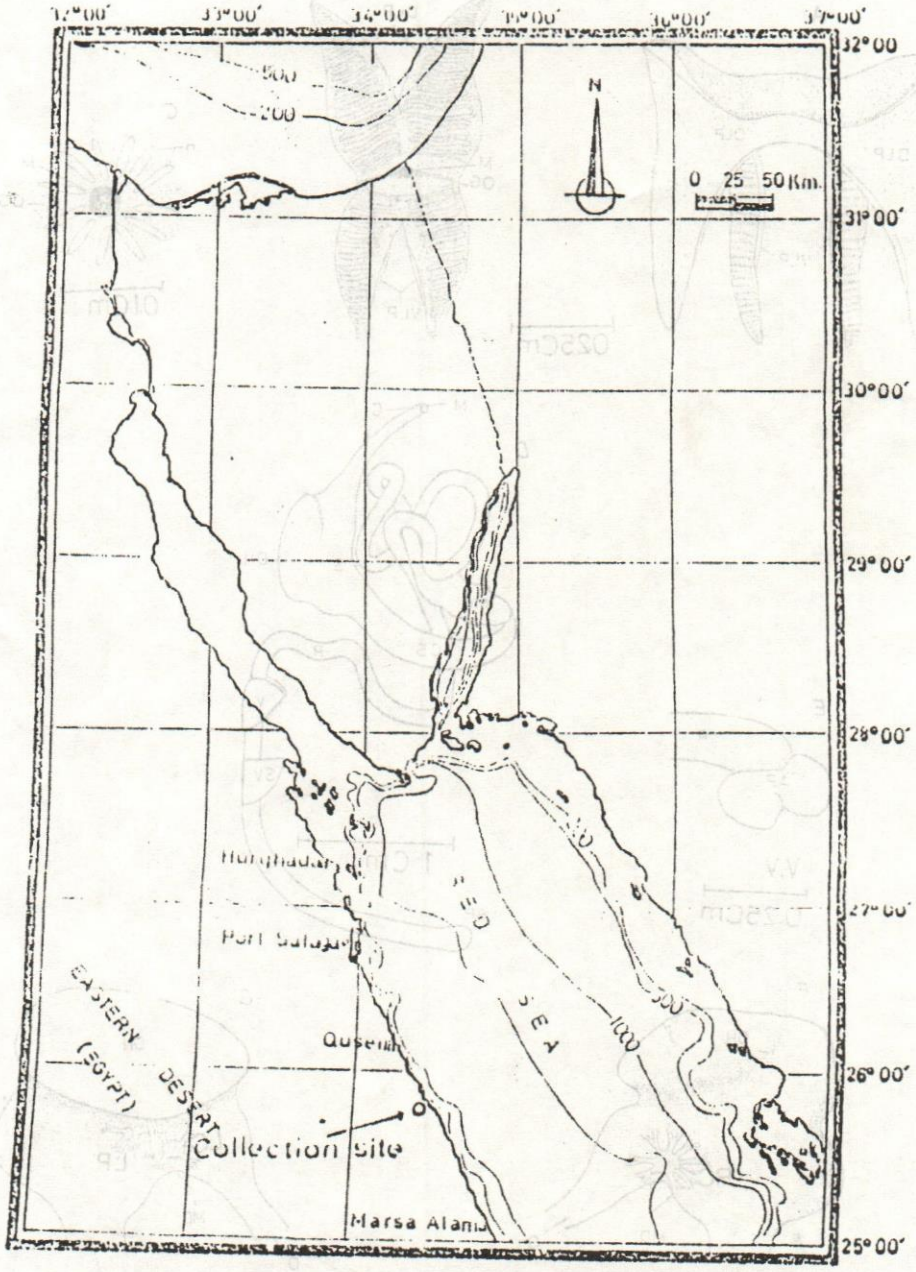

Fig. 1 B.A map of the Red Sea, showing the collection site.

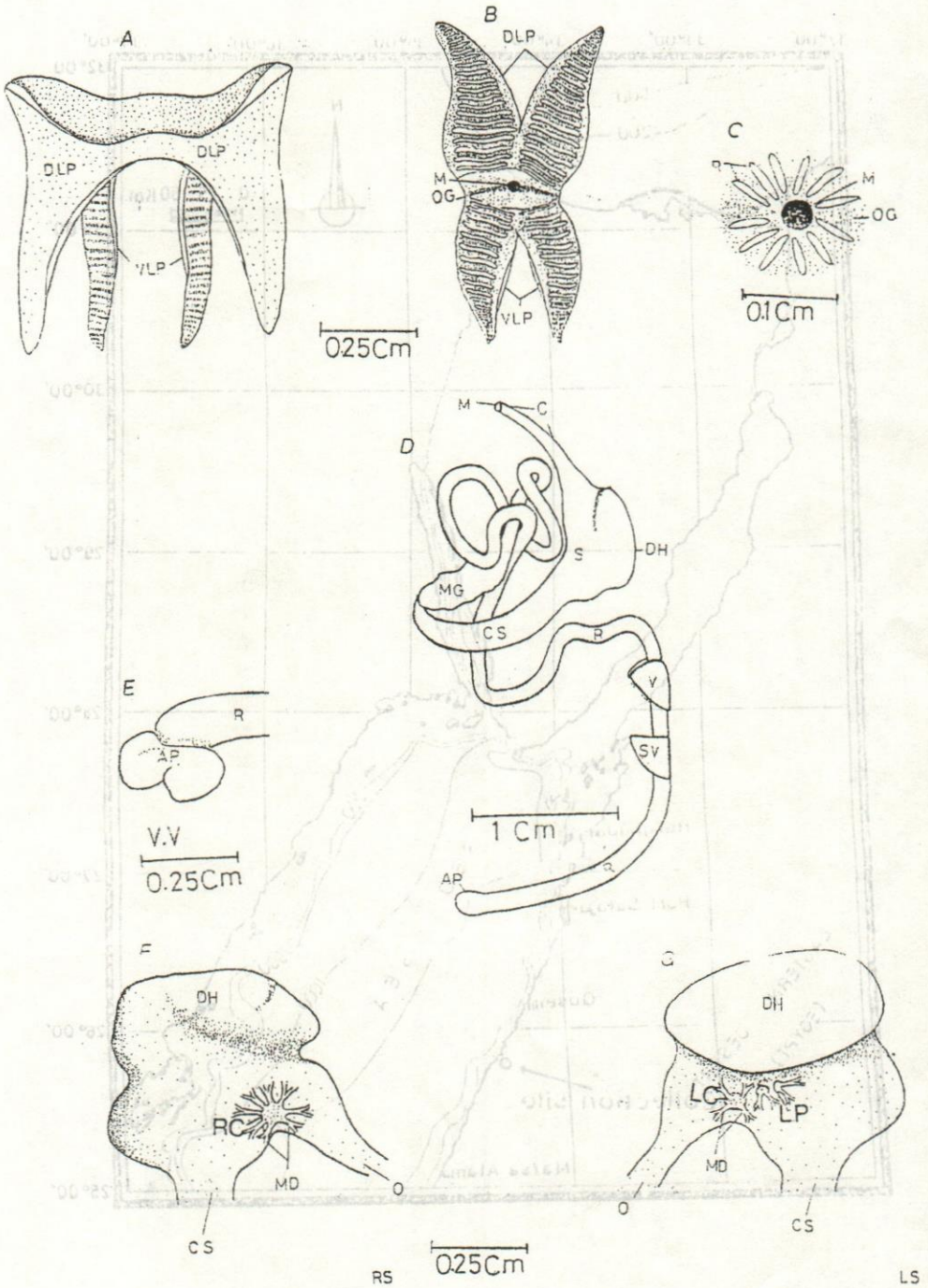
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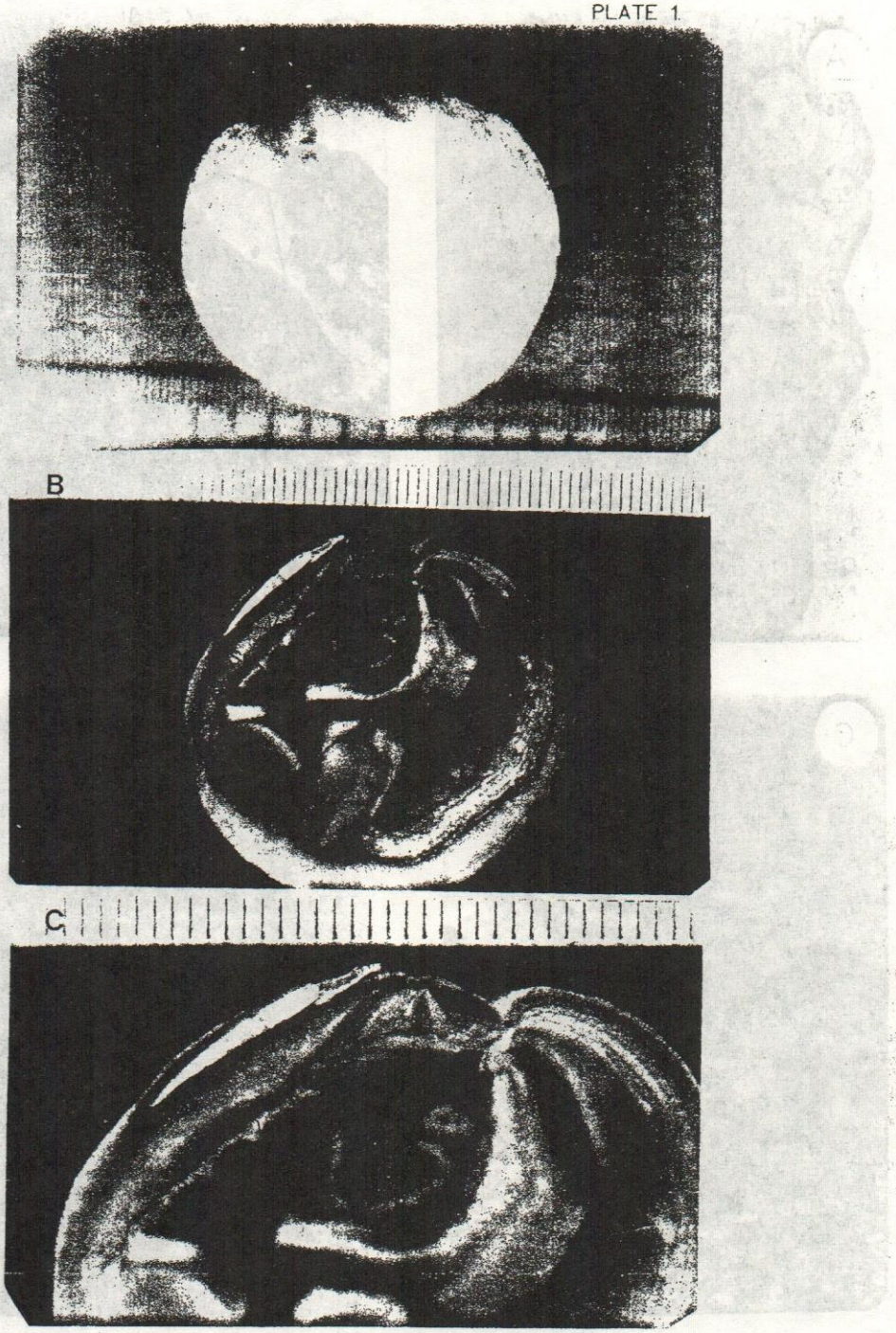
Fig. 2.

PLATE 1



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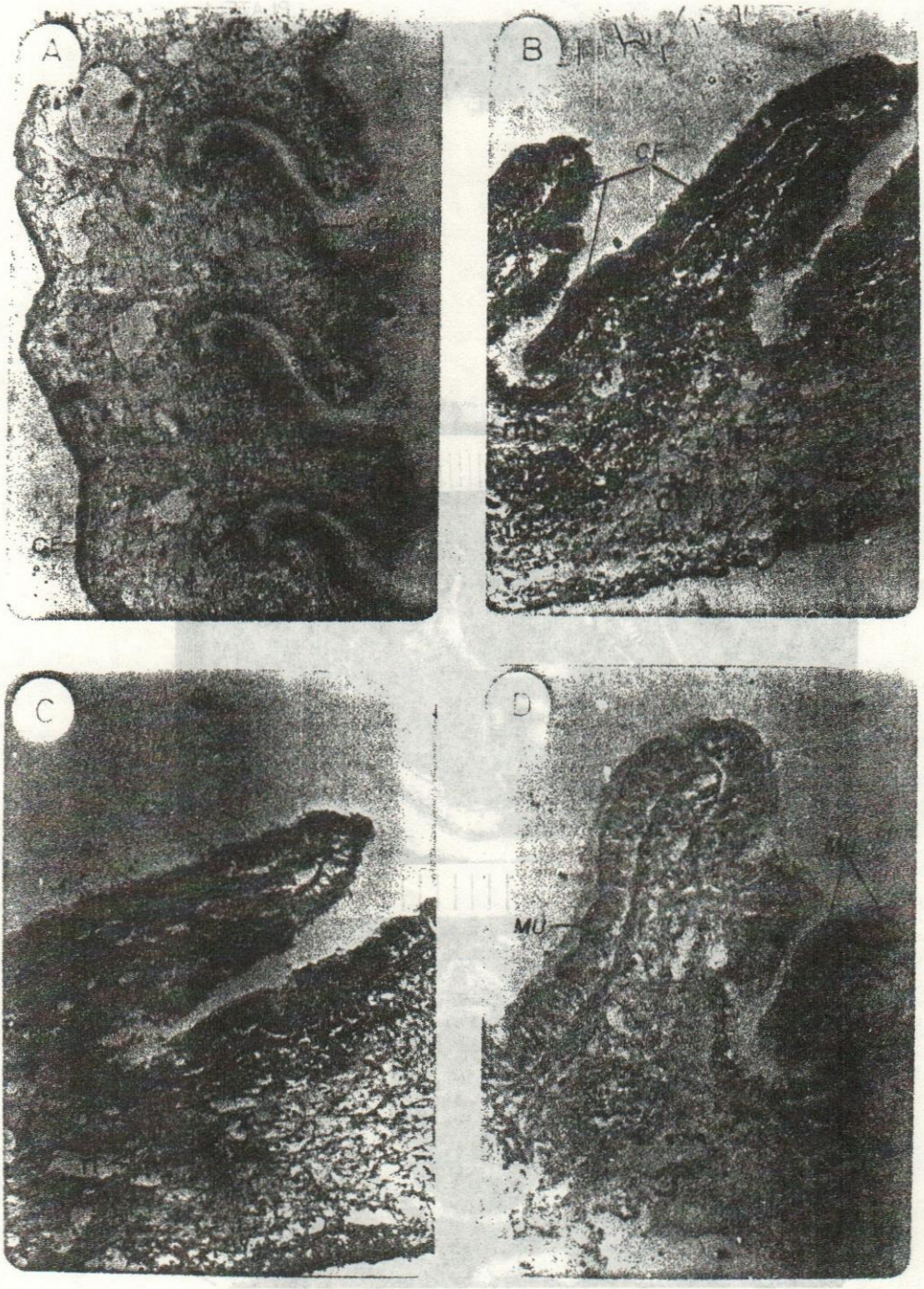

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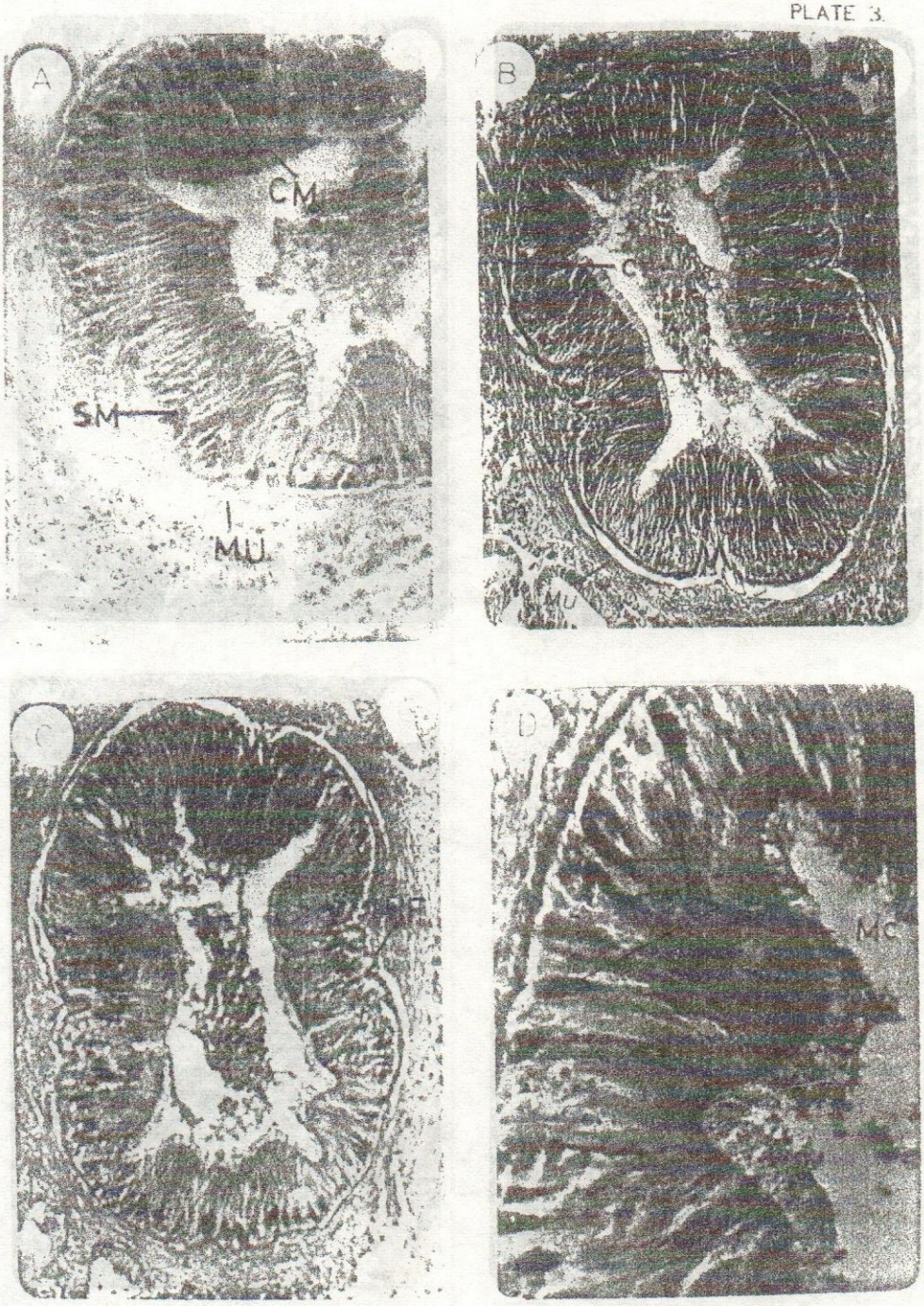

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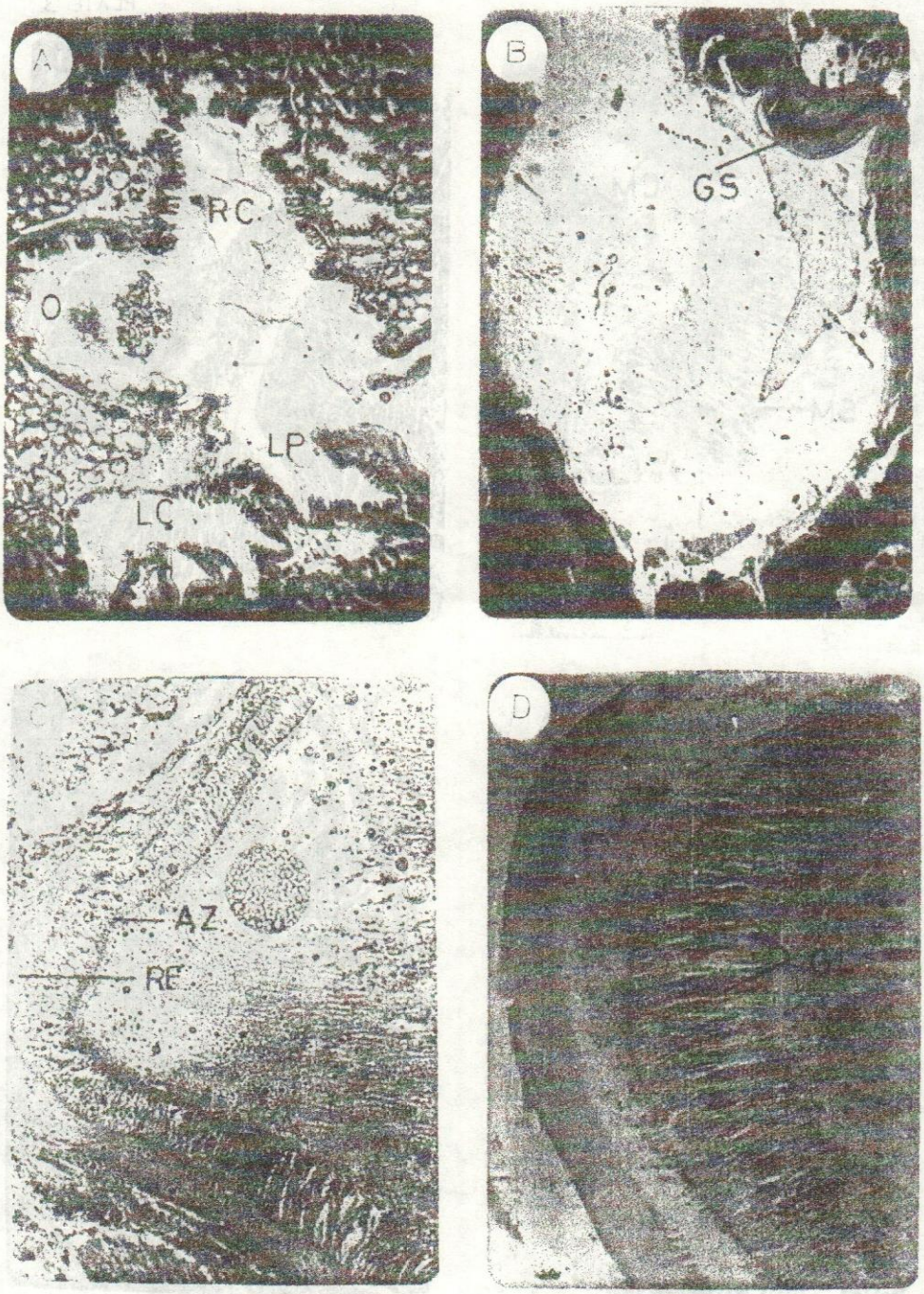

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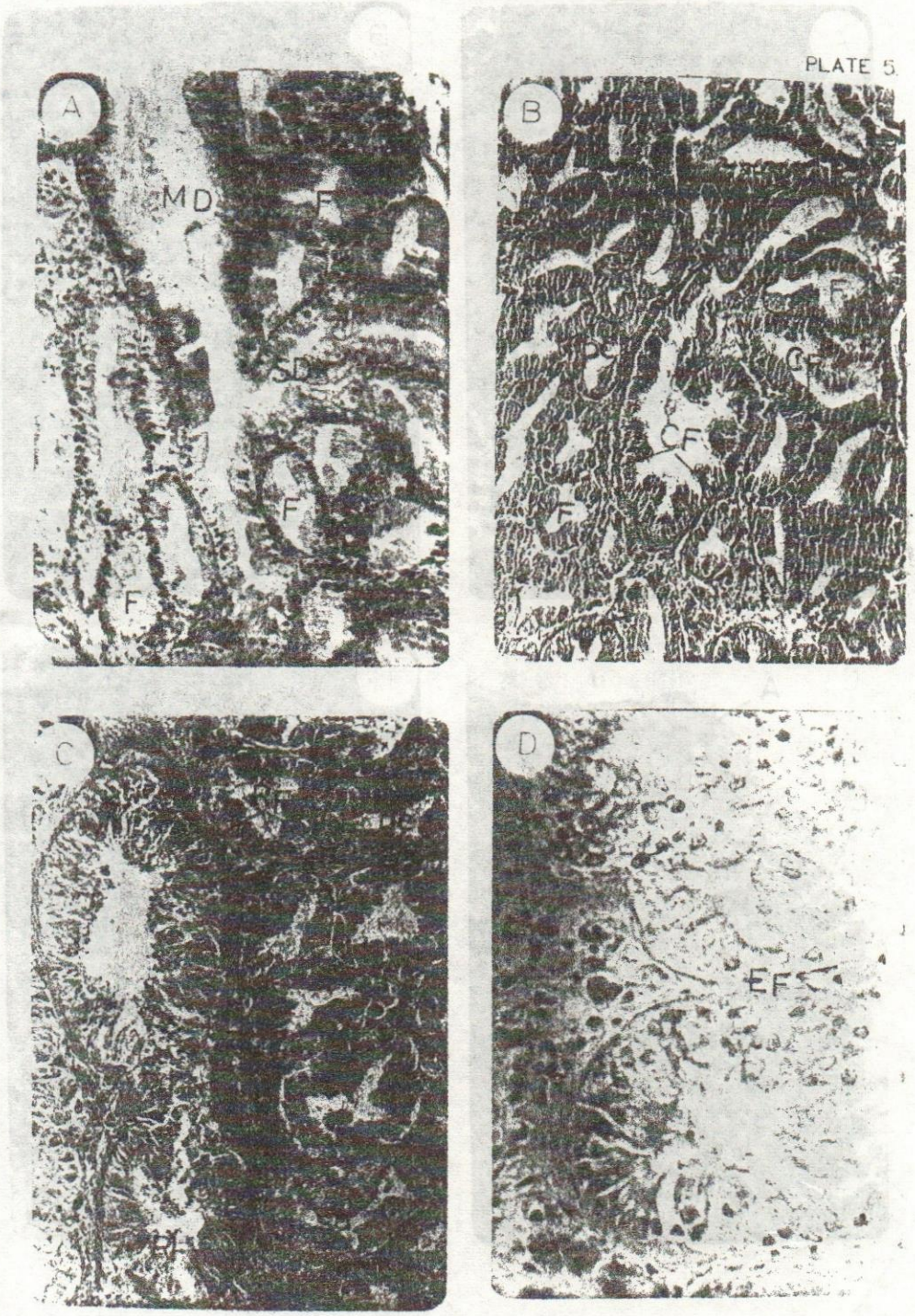

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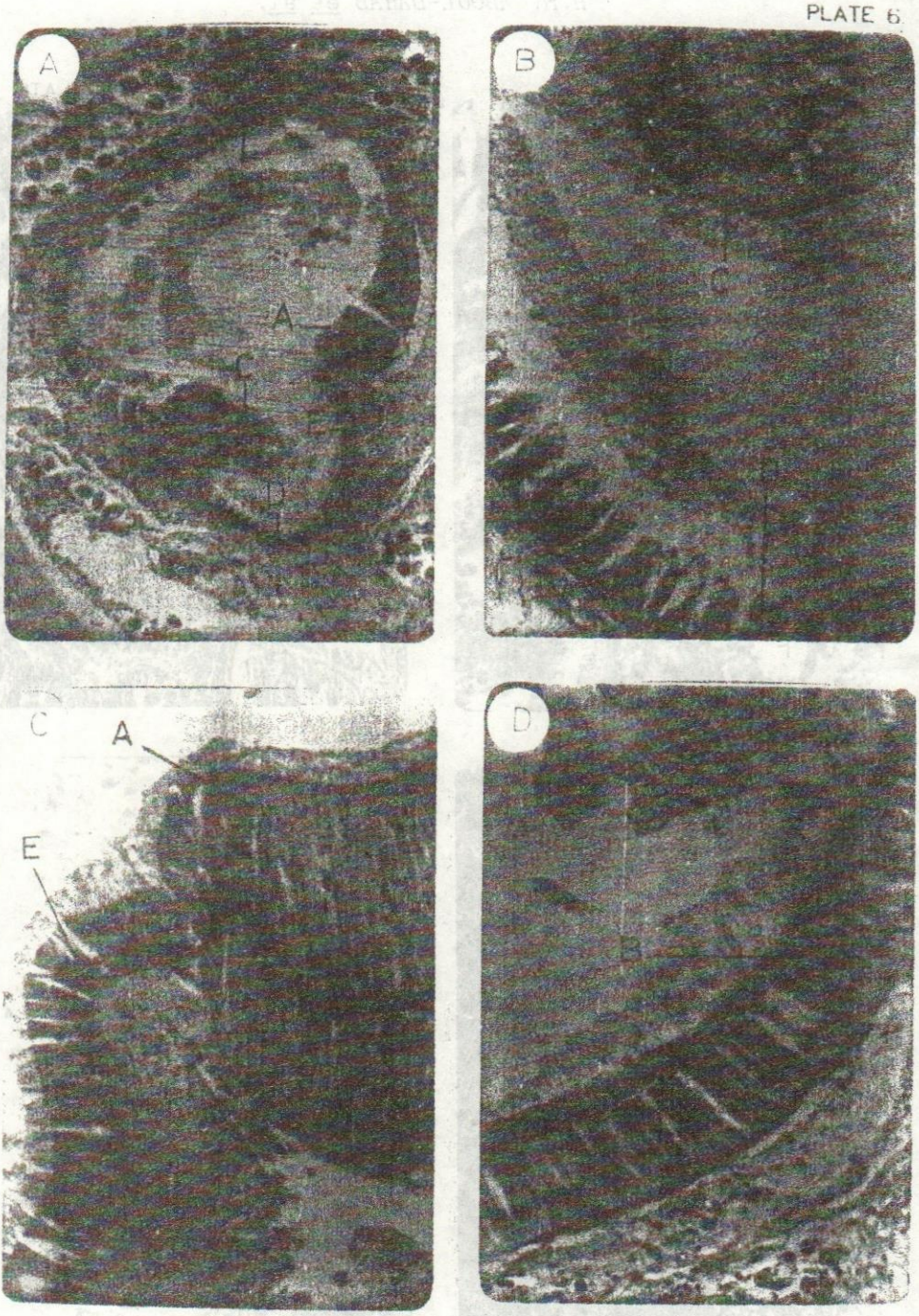

PLATE 7

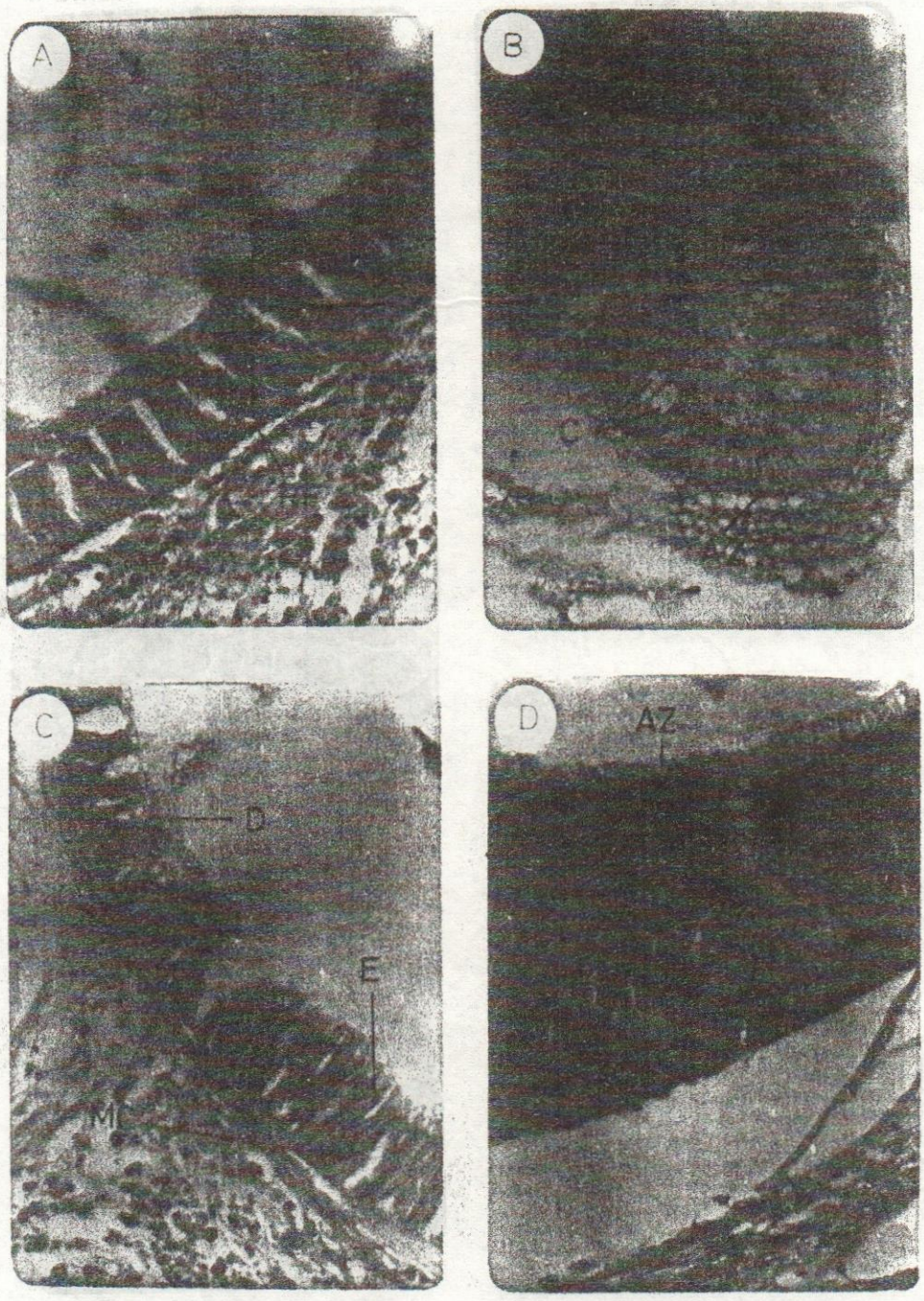

PLATE 8.