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THE DIGESTIVE SYSTEM AND FEEDING OF THE CHITON *ACANTHOPLEURA HADDONI* (MOLLUSCA, POLYPLACOPHORA) FROM THE ARABIAN GULF

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ABSTRACT

The morphology and histology of the digestive system of the chiton *Acanthopleura haddoni* are studied. This system is differentiated into alimentary canal and associated glands. The above canal starts with muscular buccal mass followed by a short oesophagus that leads to a stomach of two portions, a dorsal channel and a ventral sac. This proceeds into a long coiled intestine which is differentiated into an anterior part and a narrower posterior part that leads to a rectum which opens by an anus on the posterior extremity of the mantle cavity. The glands associated with the alimentary canal include paired salivary, sugar and digestive glands. The food and feeding behaviour of this animal are examined and the digestive mechanism is discussed.

INTRODUCTION

Acanthopleura haddoni represents one of the most common rocky molluscs in the Arabian Gulf. Early description of the anatomy and histology for different

polyplacophorans was given by some authors (Haller, 1884 and Fretter, 1937). On the other hand, the morphology, histology and physiology of alimentary tract of *Acanthopleura haddoni* collected from the Tanzanian coast was briefly studied by Greenfield (1972). The morphology of the digestive system of the same species collected from the Red Sea has been reviewed by Soliman *et al.* (1984). The radula and the morphology of the digestive tract of some polyplacophorans were described by Saito and Okutani (1989 and 1991). Age, growth, ecology and intraspecific variations of the present species were studied by Emam (1992, 1993 and 1994). No previous work has been recorded so far on the anatomy and histology of this species.

The present study aims to give a complete description of the morphology and histology of the digestive system of *Acanthopleura haddoni* with special reference on the digestion and feeding mechanism. Moreover, this study might help in the differentiation between this species and other related polyplacophorans.

MATERIAL AND METHODS

Specimens of the chiton *Acanthopleura haddoni* were collected from Ras Al-Khymah on the Arabian Gulf during 1993.

For anatomical studies, 40 specimens with 32-65 mm length were used. Their shell plates were removed and specimens were dissected. The morphology of different parts of the digestive system was drawn by camera lucida attached to a binocular microscope. The length of the radula was measured using vernier caliper. The number of transverse rows of radular teeth and the number of teeth per each row were counted. The relationships between body length of chiton, length of the radula and the number of transverse teeth rows were studied. Their constants were computed using the linear regression analysis.

For histological investigation, the digestive system of adult mature animals was dropped directly into Bouin's fluid or 10% neutral formalin fixatives. The material was then proceed for sectioning. Sections of 5 μm thickness were stained

by Heidenhan's iron haematoxylin and counter stained with eosin. The secretory cells also examined after using mucicarmine stain. Alizarin stain was used to identify calcium granules in the epithelium of the digestive gland.

The feeding behaviour was studied in the Lab using 30 adult specimens. The stomach contents of chitons collected from rocky shores were also examined under a stereo-binocular microscope and the different food items were identified.

RESULTS

The digestive tract of the chiton *Acanthopleura haddoni* starts with the mouth opening which appears as a transverse median slit. It leads into a large muscular mass that represents the first part of the alimentary tract. It is followed by a short oesophagus, sac-like stomach, coiled intestine and rectum. There are three glands associated with this tract namely; salivary, sugar and digestive glands (Fig. 1).

The Buccal Mass:

The buccal cavity within the buccal mass is greatly compressed in the dorso-ventral direction due to the presence of the radula and the odontophoral cartilage that supports the radula and the radular sac (Fig. 2).

The odontophoral cartilage is composed of muscle fibres and a large number of vesicular connective tissue cells. These cells are different in shape and size and each has a light acidophilic cytoplasm. The matrix of this cartilage contains few bundles of striated muscle fibres which enveloped by a thin layer of connective tissue.

The radular sac appears as a double-layered blind tube arises from the buccal cavity. Directly beneath the radula, the subradular epithelium consists of columnar cells which secrete chitinous radular membrane in which the radular teeth are fixed (Fig. 2). Another membrane overlying the radula is called the supra-radular epithelium which consists of low columnar cells.

The Length of radula varies from 16 to 34 mm

(24±0.69) for animals reaching 32-65 mm in length. On the other hand, their radular teeth are arranged in 80-150 transverse rows (113±3) and each row has 17 teeth. The constants (A: intercept, B: slope) of the different relationships for chiton length (L), radular length (R.L.) and number of rows (N.R.) are presented in the following Table:

	Relationship		
	L-N.R.	L-R.L.	R.L.-N.R.
N*	40	40	40
A	31.838	20.33	2.91
B	0.147	1.161	0.188
S.E.	6.135	4.479	2.877
P	<0.05	<0.001	<0.001

* N= number of chitons

The lining epithelium of the buccal cavity is mainly formed of columnar cells with elongated oval nuclei lying near the middle of the cytoplasm. A number of small pigment granules are found in the distal end of the cells. On the side walls and floor of the buccal cavity, a cuticle layer of various thickness covers this lining epithelium. The lining epithelium of the dorsal wall of the buccal cavity is formed of ciliated columnar cells without cuticle layer and has many secretory cells which are stained deeply with haematoxylin-eosin and mucicarmine (Fig. 3).

On each side of the buccal cavity, a small pouch opens dorso-laterally. Each of these has a number of folds, two of which are pronounced and projecting in the dorsal side of the lumen (Fig. 4). These folds are lined with ciliated columnar cells which have elongated oval basal nuclei. Their cytoplasm contains moderately coarse granules in its upper portion and fine granules in its lower part. The epithelial lining rests on a thick layer of connective tissue followed by two muscle layers in the form of an inner longitudinal layer and an outer circular one.

A number of elongated secretory cells are found between the ciliated columnar ones. Their cytoplasm is deeply red with haematoxylin-eosin staining (Fig. 5). They give also a strong positive reaction with mucicarmine stain. The lining epithelium of the remaining folds consists of short

ciliated columnar cells with few scattered secretory cells.

The Oesophagus:

It is a short tube extending dorsally from the buccal cavity and runs to open into the stomach. Two sugar glands open into the posterior part of the oesophagus (Fig. 1).

The lumen of the oesophagus is highly folded and its lining epithelium is formed of ciliated columnar cells. Their cytoplasm is more acidophilic and granulated. It has oval nuclei with prominent nucleoli lying near the centre of the cytoplasm (Fig. 6). Secretory cells are scattered among the ciliated ones. Their cytoplasm takes a light color with haematoxylin-eosin preparations (Fig. 7). On the other hand, these cells are stained positively with mucicarmine. The lining epithelium is followed by a layer of connective tissue and an inner circular and an outer longitudinal muscle fibres.

The Stomach:

Two distinct regions are recognized in the stomach; a dorsal channel and a ventral sac (Fig. 1). The dorsal channel is separated from the posterior end of the oesophagus by a transverse constriction and extends back between the ventral sac and the intestine. It joins the left side of the ventral sac.

Histologically, the dorsal channel is lined with ciliated columnar epithelium layer which is thrown mainly into high and low folds. Some of these high folds extend down the whole length of the dorsal channel. Secretory cells are found in their lining epithelium and are deeply stained with haematoxylin-eosin (Fig. 8).

The epithelium lining of the ventral sac is formed of non ciliated columnar cells covered by a layer of thin cuticle (Fig. 9). Their cytoplasm is granulated and contains rounded basal nuclei. Mucicarmine positive secretory cells are scattering between the columnar cells. The musculature of the ventral sac is well developed and is formed of an outer longitudinal and inner layers of muscle fibres.

Intestine:

This arises from the left side of the ventral sac of the stomach (Fig. 1). The intestine is thrown into complex coils and is divided into an anterior relatively short part and a long narrow posterior region.

a- The anterior intestine:

The anterior intestine has internally two pronounced longitudinal ridges running down throughout its whole length and enclose a gutter between them (Fig. 10). The lining epithelium of this gutter consists of low ciliated columnar cells while those of the ridges are high ciliated ones. Cells of the lining epithelium of the remainder region are similar to those described in the ridges but about half their height and with a great number of secretory cells (Figs. 10 & 11). The secretion of these cells is deeply stained with mucicarmine.

b- The posterior intestine:

In the transitional region between the anterior and posterior intestine there is a constriction separating them from each other. Numerous fecal pellets are observed inside its lumen.

The posterior intestine has from 12-15 folds of various width and heights (Fig. 12). Each fold contains two types of cells: ciliated and secretory cells. The former are greater in number and their cytoplasm is slightly stained with haemtoxylin-eosin and contains granules of moderate size. The secretory cells have narrow apical regions and wide basal ones. They have oval basal nuclei and numerous droplets that are deeply stained with both haematoxylin-eosin and mucicarmine (Fig. 13).

The Rectum:

This is a short tube which opens to the exterior by the anus. Its lumen is relatively wider than that of the posterior intestine and has less pronounced internal folds. Its lining epithelium is formed of ciliated columnar cells of uniform height. The cytoplasm contains minute granules at its apical region. Their nuclei are oval and lying near the central region of the cells (Fig. 14).

The Salivary Glands:

These are one pair of glands that open directly on each side of the buccal cavity (Fig. 1). They are compound saccular glands and lined by two types of epithelial cells; a narrow wedge shaped secretory cells, and columnar ones (Fig. 15).

Sugar Glands:

These are two glandular sacs that lie ventrally to the posterior part of the oesophagus and open through a common duct into it (Fig. 1). Numerous short thin-walled villi occupy the cavity of these glands.

In cross section, the lining epithelium appears highly folded and consists mainly of secretory cells. The cytoplasm of these cells is highly granulated and deeply stained with haematoxylin-eosin, and gave a positive reaction with mucicarmine. The nuclei are nearly spherical and lie in the basal region of the cells (Fig. 16).

Wedge-shaped cells are found between the secretory cells. Their cytoplasm is lodged with a large number of spherules.

The Digestive Glands :

This consists of two lobes that surround the greater part of the stomach and fill the spaces between the coils of the intestine (Fig. 1). These lobes are composed of large number of blind tubules and open by two ducts into the ventral sac of the stomach. The orfices of which are protected by a sphincter muscles and lie close to the origin of the anterior intestine at the posterior part of the left side of the ventral sac.

In cross section, the digestive gland is formed of a great number of either round or oval tubules which are separated from each other by a sheet of connective tissue. The lining epithelium of these tubules is formed of two kinds of cells, large vacuolated cells and small pyramidal ones (Fig. 17). The former is more numerous and are elongated, with acidophilic cytoplasm and have basal nuclei. They contain large secretory granules, but often with aggregated small ones. Some of these cells appear at an advanced stage of secretory activity, being non vascular with broken outer boarder, and their secretory products are

released in the lumen of the tubules. The second type is present either singly or in groups of 2-3 cells each. The cytoplasm is usually crowded with a variable number of granules which are stained red with alizarin. This indicates that these granules are of calcium origin.

Food and Feeding Behaviour

Specimens of *A. haddoni* were collected from flat reefs during the low tide. They were found among comunities of barnacles; *Balanus sp.*, *Cthamalus sp.*, and the bivalves; *Crassosterea sp.* and *Mytilus sp.* The rocks were covered by blue green algae. Many grooves scraped by the hard radular teeth of these chitons were observed on the rocks where they live. This is mainly attributed to the feeding behaviour of the animal on algae that grown on that rocks.

In the Lab, 30 chitons were divided into two equal groups. The first of them were left in glass aquaria with rocks covered with algae. These animals were mainly feed at night for a period of about 7 hours. The other group were left in aquaria without food. They were found to scrap the glass at night. This indicates that feeding behaviour of these animals seems to be regulated by night darkness. Moreover, chitons in these aquaria were found to be aggregated in small groups after few days of fasting. Their radulae were observed to scrap the calcareous spicules on the mantle girdles of each other.

Examination of the stomach contents of chitons collected from the field revealed that among the main components of the stomach are fragments of blue green algae. Diatoms, rock fragments, calcareous spicules, larvae of barnacles and bivalves are represented in smaller quantities.

DISCUSSION

The morphology and histology of the digestive system of the chiton *Acanthopleura haddoni* has been so far not examined before. However, the basic plan of organization of this system has been found to conform with the picture of the structure described in other members of Polyplacophora with the exception of certain

features such as the length and dimensions of certain parts, degree of coiling of the intestine, length of radula and number of its rows of teeth. These differences were used to differentiate between the species of polyplacophorans (Fretter, 1937; Soliman *et al.* 1984; Saito and Okutani, 1989 and 1991). Moreover, the number of teeth in each radular row was varied among the different molluscs (Alexander, 1987). In the present study, it is 17 teeth in *A. haddoni*, while it was 11 teeth in the aplacophoran *Neoplina sp.* (Purchon, 1978). In the gastropod snails *Helix pomatia* and *Patella sp.*, it was 151 and 13 teeth, respectively (Alexander, 1987).

The constants (A & B) computed for the relationships between chiton length, radula length and number of transverse rows of teeth can be used as a simplest method for inter- and intraspecific differentiation between various polyplacophorans (Saito and Okutani, 1989).

Histologically, the structure of the oesophagus, dorsal channel of stomach, intestine and rectum of *A. haddoni* agrees well with the description given by Fretter (1937) on *Lepidochitona cinereus* and *Acanthochitona crinitus* and Greenfield (1972) on *A. spinger*. Moreover, both the large and pyramidal cells described in the lining epithelium of the digestive gland in the present study were similar to the absorbing and lime cells reported by Fretter (1937) in the digestive gland of *L. cinereus* and *A. crinitus*.

The positively stained alizarin granules observed in the epithelial cells of the digestive gland in the present investigation revealed that this animal feeds sometimes on rock fragments and calcareous materials which are stored as calcium droplets in these cells.

On the other, hand, the secretory cells in the lining epithelium of the different digestive organs of the present chiton were positively stained with mucicarmine. This indicates that these cells were mucous cells and they are similar to that recorded by Fretter (1973).

The present morphological and histological structures of

the different digestive organs reflect the digestive mechanism in this group of animals. The long radula with its sharp teeth helps in rasping algae and other hard fragments of rocks and bringing them to the buccal cavity of the chiton. The salivary glands pour their secretion directly into this cavity to be mixed with food particles. Huang and Giese (1958) reported that the secretion of these glands in some polyplacophorans contains maltase enzyme. The secretory cells in the buccal cavity secrete mucus to lubricate the passage of food particles into the oesophagus. The cilia of the lining epithelium of the oesophagus carry the food string backwards to the dorsal channel of the stomach. The secretory cells of the two sugar glands pour their secretions into to this channel. Meeuse and Flugel (1958) found that these secretions contain amylase enzyme. The ciliated high folds of the dorsal channel allow the passage of this mixture of food and enzymes into the ventral sac of the stomach. The secretion of the digestive glands passes to the ventral sac. The presence of cuticle and outer thick muscular coat of this sac help the food particles to be thoroughly mixed with the digestive enzymes of the digestive gland. The absorbing function of the digestive gland was detected by the presence of vacuoles occupied by digestive inclusions in its large cells.

The present investigation revealed that *A. haddoni* is a nocturnal animal and feeds for a period of about 7 hours. The presence of great quantities of blue green algae and few calcareous materials in the stomach contents of this chiton is attributed to their dominance on the flat rocks covered with algae where the animals live. Larvae of some crustaceans and molluscs were probably consumed only incidentally while feeding due to their presence or settlement on the algae. Glynn (1970) reported that *Acanthopleura granulata* and *Chiton tuberculatus* largely feed at night for a period of an average 8 hours on different species of blue green algae. He also found that a considerable quantity of rock fragments, comprising up to 40% (dry weight) of the total material removed, is also

ingested. Greenfield (1972) mentioned the presence of large amount of blue green algae and diatoms in the stomach contents of the chiton *A. spinger*, while Bode (1989) observed great proportion of calcareous substances in the gut of *Acanthochitona crinitus*.

The present studies as well as other investigations indicated that the diet of polyplacophorans consists mainly of carbohydrates from algae and diatoms in addition to few quantities of protein either from the growing tips of algae or from larvae. The great variety of diets in this group is mainly due to the particular structure of their radular apparatus and the structure of the digestive system (Purchon, 1978).

The present observation is deemly important for future histochemical and biochemical studies especially on the different glands and secretory cells in order to indicate their specific functions and their roles in the digestive mechanism.

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REFERENCES

ALEXANDER, R.M. (1987): The invertebrates. Cambridge Univ., London., 553 pp.

BODE, A. (1987): Production of the intertidal chiton *Acanthochitona crinitus* whitin a community of *Corallina elongata*. **J. Moll. Stud., 55:** 37-44.

EMAM, W.M. (1994): Ability of the chiton *Acanthopleura haddoni* (Mollusca; Polyplacophora) to withstand some ecolgical stresses. **J. Egypt. Ger. Soc. Zool., 13 (D):** 299-315.

EMAM, W.M and ISMIL, N.S. (1992): Intraspecific variation in the morphometrics of *Acanthopleura haddoni*

(Mollusca; Polyplacophora) from the Arabian Gulf and Gulf of Oman. **J. Egypt. Ger. Soc. Zool., 8 (B):** 249-266.

EMAM, W.M and ISMIL, N.S. (1993): Age and growth of the common rock chiton *Acanthopleura haddoni* from United Arab Emirates. **J. Fac. Sci. U.A.E. Univ., 5 (1):** 73-83.

FRETTER, V. (1937): The structure and function of the alimentary canal of some species of Polyplacophora. **Trans. Roy. Soc. Edin., 59:** 119-164.

GREENFIELD, M.L. (1972): Feeding and gut physiology in *Acanthopleura spiniger* (Mollusca). **J. Zool. Lond., 188:** 37-47.

GLYNN, P.W. (1970): On the ecology of the Caribbean chitons *Acanthopleura granulata* Gmelin and *Chiton tuberculatus* Linne; density mortality, feeding, reproduction and growth. **Smithsonian Contribution to Zoology, 66:** 1-21.

HALLER, B. (1884): Die organisation der chitonen der Adria. **Arb. Zool. Inst. Univ. Wien, 5:** 29-41.

HUANG, H. and GIESE, A.C. (1958): Tests for digestion of algal polysaccharides by some marine herbivores. **Science, N.Y., 127:** 475-620.

MEEUSE, B.J. and FLUGEL, W. (1958): Carbohydratases in the sugar gland of Cryptochiton (Polyplacophora, Mollusoa). **Nature, Lond., 181:** 699-700.

PURCHON, R.D. (1978): The biology of the Mollusca. Pergamon Press, Oxford, N.Y., Toronto, Sydney, Paris, Frankfurt (2nd ed.). 500 pp.

SAITO, H. and OKUTANI, T. (1989): Revision on shallow-water species of the genus *Placiphorella* (Polyplacophora; Mopaliidae) from Japan. **Veliger, 32(2):** 209-227.

SAITO, H. and OKUTANI, T. (1991): Taxonomy of *Mopalia* and *Plaxiphora*

(Poyplacophora; Mopaliidae). **Veliger, 34(2):** 172-194.

SOLIMAN, N.G., GHOBASHY, A.A., and GUIRGUIS, A.N. (1984): On the common roch chiton *Acanthopleura spiniger* (Sowerby, 1839) from the northwestern Red Sea. **Bull. Fac. Sci., Cairo. Univ., 52:** 133-154.

LEGEND OF FIGURES (2-17)

Sectors of transverse sections of different organs of the digestive system of *Acanthopleura haddoni* stained with haematoxylin and eosin.

Fig. 2: Photomicrograph of the odontophore cartilage and radular teeth in the buccal cavity. X150

Fig. 3: Photomicrograph of the lining epithelium of the dorsal wall of the buccal cavity with numerous secretory cells. X300

Fig. 4: Photomicrograph of the buccal pouch with its two pronounced ciliated folds. X150

Fig. 5: Enlarged sector of the lining epithelium of Fig. 4 X600

Fig. 6: Photomicrograph of the oesophagus with its ciliated folds. X150

Fig. 7: Enlarged sector of the lining epithelium of Fig. 6. X600

Fig. 8: Photomicrograph of the lining epithelium of the dorsal channel of stomach with numerous secretory cells. X600

Fig. 9: Photomicrograph of the lining epithelium of the ventral sac of stomach with its cuticle. X300

Fig. 10: Photomicrograph of the anterior intestine with two pronounced ciliated folds. X150

Fig. 11: Enlarged sector of Fig. 10. X600

Fig. 12: Photomicrograph of the posterior intestine. X150

Fig. 13: Enlarged sector of Fig. 12. X600

Fig. 14: Photomicrograph of the cilated lining epithelium of the rectum. X300

Fig. 15: Photomicrograph of the lining epithelium of salivary gland. X300

Fig. 16: Photomicrograph of the lining epithelium of sugar gland. X300

Fig. 17: photomicrograph of the lining epithelium of the digestive gland with its large and pyramidal cells. X600

ABBERVIATIONS

bc	Buccal cartilage
cl	Cilia
cu	Cuticle
lc	Large cell
rt	Radular teeth
pc	Pyramidal cell
sc	Secretory cell
v	Vacuole
wc	Wedge-shaped cell

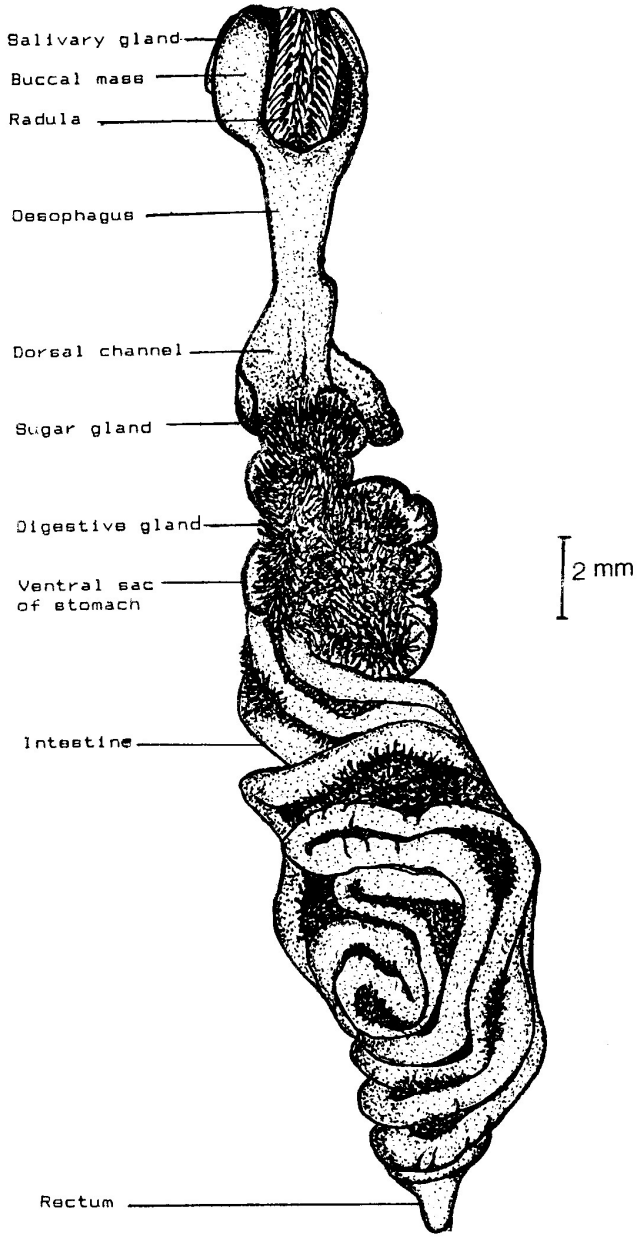
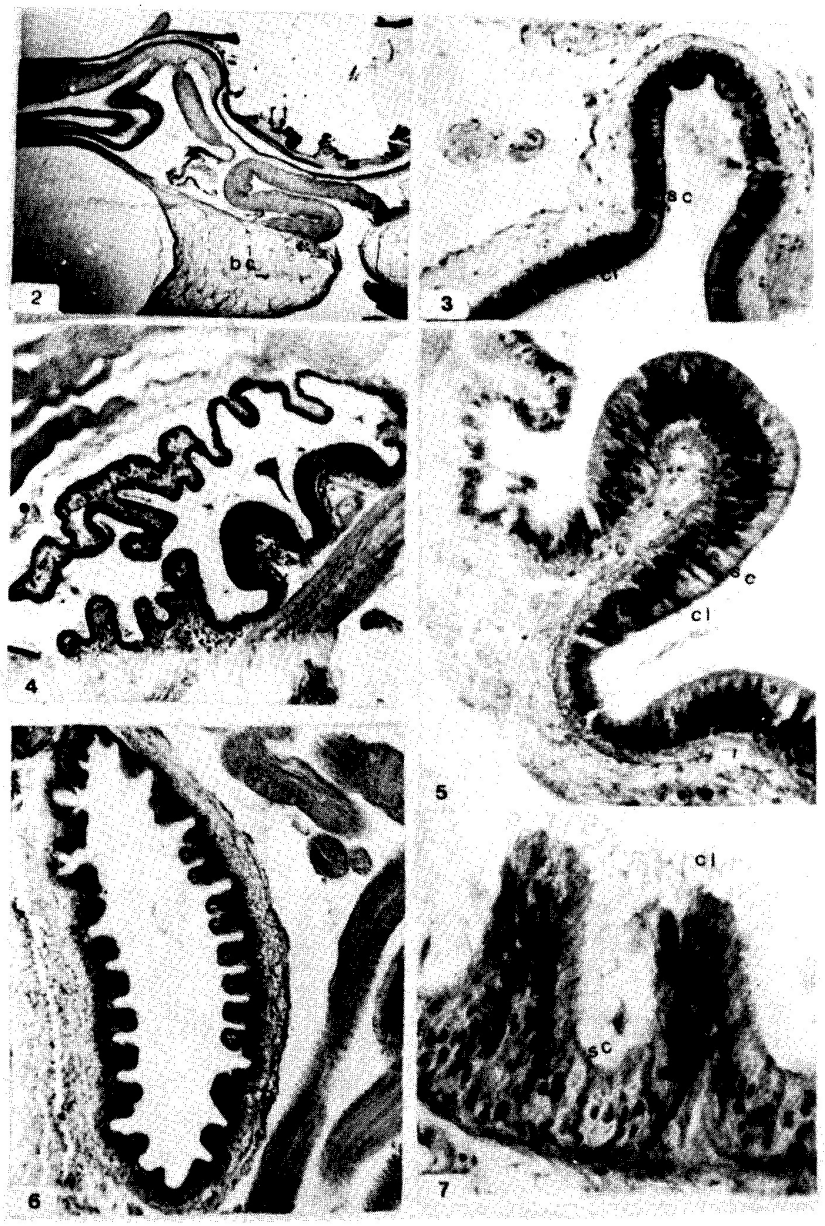
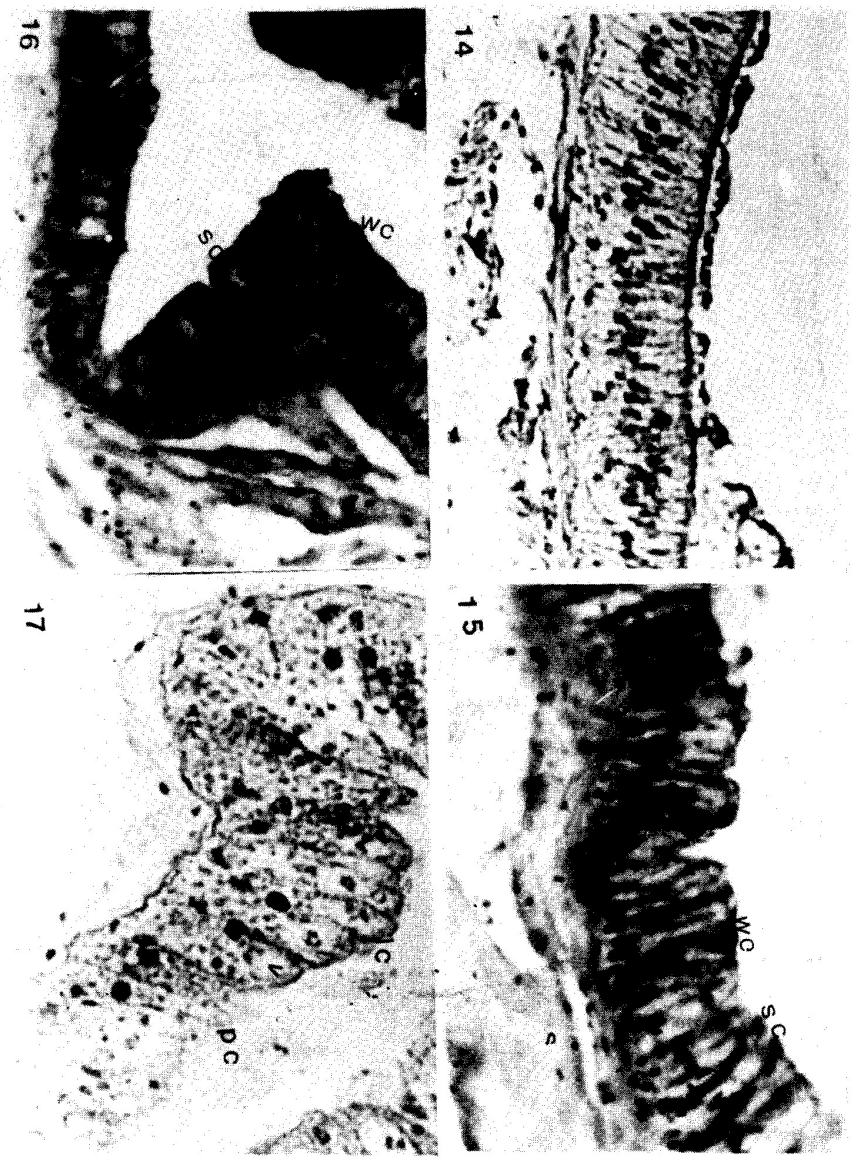


Fig. 1. Dorsal view of the digestive system of Acantopleura haddoni





الجمعية المصرية - الألمانية لعلم الحيوان
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الجهاز الهضمي والتغذيه في الكيتون "اكانثوبلورا هادوني"

(الرخويات - الكيتونات) من الخليج العربي

وحيد محمود امام - عبد الحليم عبده سعد
قسم علم الحيوان - كلية العلوم - جامعة عين شمس

اشتمل هذا البحث على الوصف المورفولوجي والنسيجي للجهاز الهضمي للكيتون اكانثوبلورا هادوني حيث تمت دراسة التراكيب المختلفه والمتمثله في الكتله الفميه - المرئ - الامعاء والمستقيم بالاضافه الى ثلاثة ازواج من الغدد الملحقه وهى الغدد اللعابيه ، الغدد السكريه والغدد الهاضمه . كما تمت مقارنة هذه التراكيب مع نظيراتها في الانواع الاخرى المنتميه لنفس المجموعه ثم نوقشت علاقة تلك التراكيب مع وظائفها بالاضافه الى دراسة محتوى المعدة وسلوك تغذية هذا الحيوان .

السيد الاستاذ الدكتور

مقرر اللجنة العلمية الدائمة لترقى أعضاء هيئة التدريس – علم الحيوان

تحيـــة طيبـــة وبعـــــد :

نتشرف باحاطة سيادتكم علما بدور كل منا فى البحث المعنون :

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د.حيد محمـــود امـام : شارك فى وضع الفكرة وساهم فى التنفيذ واعداد البحث للنشر .

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وتفضلوا سيادتكم بقبول وافر التـــحية.

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