THE FUNCTIONAL MORPHOLOGY OF THE FORE-GUT OF THREE SPECIES OF DECAPOD CRUSTACEA: *CYCLOGRAPSUS PUNCTATUS* MILNE-EDWARDS, *DIOGENES BREVIROSTRIS* STIMPSON, AND *UPOGEBIA AFRICANA* (ORTMANN)

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INTRODUCTION

In animals the digestive system is, physiologically, always closely related to the type of food eaten. In decapod crustaceans the stomachs contain very complicated morphological structures. It was decided to examine these structures and their possible functions and to determine whether their appearance and function is also related to the type of food eaten. For this examination, three southern African decapods were chosen because little descriptive work on the functional aspects of their foreguts has been done. Literature dealing with foreign and related forms, however, is considerable, but no attempt has been made to review it.

The chosen species differ widely in their diet. According to Alexander and Ewer (1969) the crab *C. punctatus* is a general scavenger which eats large pieces of food, including coarse vegetable matter and small animals (isopods, zoaea, polychaets). Before entering the stomach the food is shredded by the chelae and sliced by the mandibles. Boltt (1961) found that the hermit crab *D. brevirostris* feeds on fairly fine particles such as algae which is filtered from the water by the antennae. According to MacGintie (1930) and Hill (1967) the mud shrimps, *Upogebia sp.*, filter extremely fine food particles from the water by the setae of the first and second peripods; only fine particles are eaten, large particles being rejected.

GENERALISED DESCRIPTION OF A DECAPOD FORE-GUT

A morphological and functional description of a generalised decapod fore-gut is given first, so that the complicated system found in the actual animals can more easily be understood. For this generalised description a fore-gut has been illustrated diagrammatically in Figure 1(i). The lettering in this figure is the same as that shown in the illustrations of the actual fore-gut (Figs. 4, 5 and 6, 7 and 8, 9).

This generalised account is based on the earlier work of Younge (1924) and Patwardhan (1934) as well as on the results of the present investigation.

MORPHOLOGY (FIG. 1)

The fore-gut consists of two regions: anteriorly, a large cardiac-stomach (CARDIAC—Fig. 1 (i)), into which the oesophagus opens; and posteriorly, a smaller pyloric-stomach

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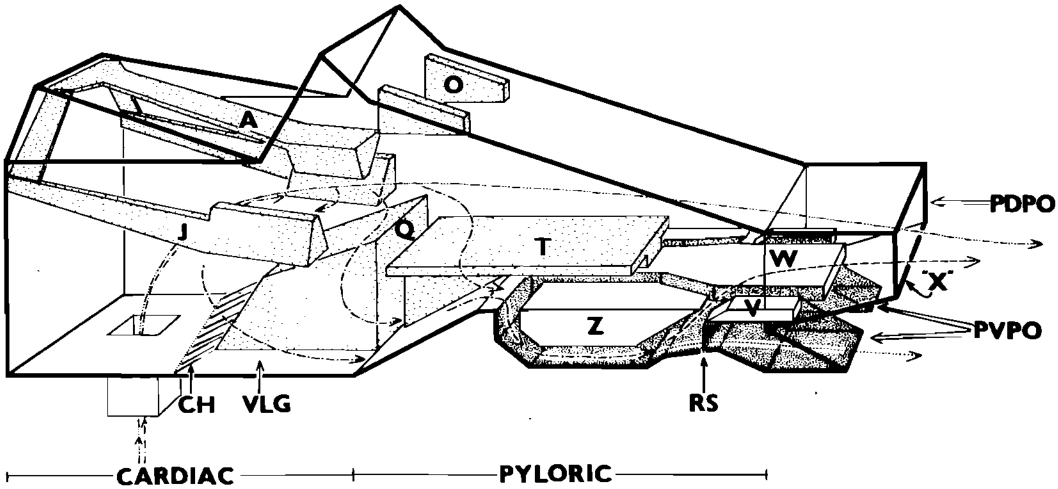
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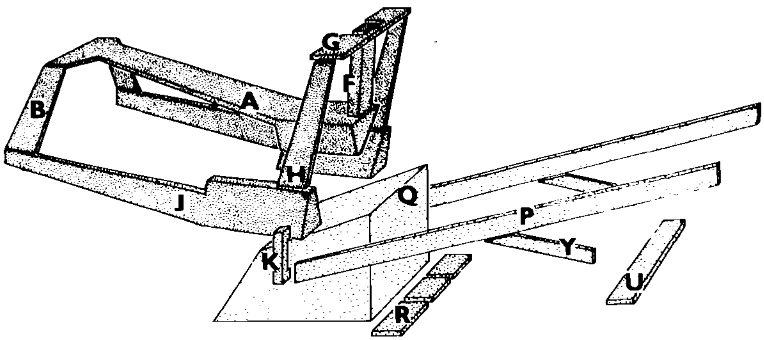
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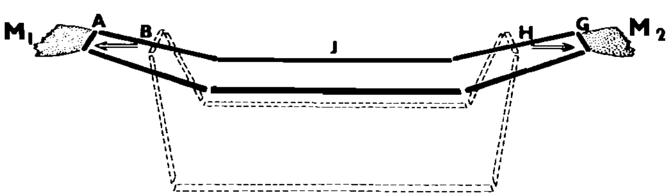
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(PYLORIC—Fig. 1 (i)), which eventually leads, via a posterior dorsal pyloric-opening (PDPO—Fig. 1 (i)) and posterior ventral pyloric-openings (PVPO—Fig. 1 (i)) into the hind-gut and digestive glands respectively. The cardiac-stomach communicates with the pyloric-stomach via three openings: one dorsal opening and two ventro-lateral openings. The dorsal opening is bounded laterally by a pair of cardio-pyloric valves (O—Fig. 1 (i)) and ventrally by a median cardio-pyloric valve (Q—Fig. 1 (i)). The ventro-lateral openings are situated one on either side of the median cardio-pyloric valve Q, and are known as the ventro-lateral grooves (VLG—Fig. 1 (i)). The anterior openings of the ventro-lateral grooves (VLG), in the cardiac-stomach, are covered by a comb of setae (CH—Fig. 1 (i)) while posteriorly, each groove opens into a filtering apparatus (Z—Fig. 1 (i)).

The wall of the fore-gut is mostly membranous, but is strengthened at various places by calcified plates or ossicles. These ossicles are joined to one another by ligaments so that they can hinge about their points of attachment. They act mainly as a skeleton to support the membranous wall. In the dorsal wall of the cardiac-stomach of all three species there is a large ossicle, A (Fig. 1 (ii)), which bears a single tooth known as the dorsal tooth, while in the lateral wall there is a pair of strong ossicles, J (Fig. 1 (ii)), which also each bear a tooth; these are known as the lateral teeth. The teeth together with the ossicles that operate them comprise the gastric mill.

FUNCTION (FIG. 1)

Function of the Fore-gut (*Fig.* 1 (*i*))

Food, from the oesophagus, enters the cardiac region of the fore-gut. According to Younge (1924) digestive juices, from the digestive gland, enter the pyloric-stomach and move forewards to the cardiac-stomach where they mix with the food. The mixture is then ground to a pulp of particles and liquids by the gastric mill. Particles too large to enter the ventro-lateral grooves pass straight backwards into the hind-gut. Finer particles and liquids which can, however, enter the ventro-lateral grooves, move back into the filters where they are separated. The finer particles are then also passed into the hind-gut, while the liquids enter the digestive gland.

FIGURE 1

Generalised diagrams of a decapod fore-gut: (i) Perspective diagram of a fore-gut. The outer walls are transparent. Paths taken by the food through the fore-gut are shown by broken lines: Coarse particles —...—...—...> Fine particles and liquids —.—.—.> Fine particles — — — — —> Liquids.......... > (ii) Perspective diagram of fore-gut ossicles: the gastric mill ossicles are more heavily shaded. (Figs. li and lii are seen from the same view point.) (iii) Diagrammatic dorso-lateral view of gastric mill frame work ossicles. When muscles M1 and M2 contract the frame work is lengthened in the direction of the arrows. Key to lettering: A—urocardiac ossicle, B—pterocardiac ossicle, F—propyloric ossicle, G—pyloric ossicle, H—exopyloric ossicle, J—zygocardiac ossicle, K—sub-dentary ossicle, O—lateral cardiac pyloric valve, P—lateral pyloric ossicle, Q—cardio-pyloric valve, R—anterior supra ampullary ossicle, S—supra-ampullary fold, T—inter ampullary ridge, U—posterior supra ampullary ossicle, V—inferior ampullary fold, W—median dorsal lappet, Y—median supra ampullary ossicle, Z—ampullary, or filter, region. CH—comb of setae, PDPO—posterior dorsal pyloric-opening, PVPO—posterior ventral pyloric-opening, RS—rods and setae, VLG—ventro-lateral groove, "X"—continuation of the pyloric floor of which X is a part.

The way in which the gastric mill grinds food to a pulp and the way in which the filtering apparatus separates liquids from fine particles, will now be described in detail.

Function of the Gastric mill (*Figs.* 1 (*ii*), 1 (*iii*))

The ossicles of a generalised decapod fore-gut are shown in Figure 1 (ii); the gastric mill ossicles are more heavily shaded.

In the living animal, the dorsal tooth fits between the two lateral teeth. Extrinsic muscles inserting on the anterior edge of ossicle A can pull it forwards, so that the dorsal tooth (which is situated on ossicle A) slides forwards between the two lateral teeth. Simultaneously a posterior extrinsic muscle, inserting on ossicle G or ossicles H contracts. Its contraction pulls ossicle G and ossicles H posteriorly; but as ossicles H are linked to ossicles J, ossicles J are also pulled backwards slightly. The two lateral teeth (situated on ossicles J) thus move slightly posteriorly as the dorsal tooth slides forwards over them. Since the anterior and posterior muscles pull in opposite directions, they also, besides moving the teeth relative to each other, lengthen the gastric mill framework. Lengthening of the framework causes ossicles J to move both dorsally and medially. This is illustrated in Figure 1 (iii), which is a diagram of the framework drawn from a dorso-lateral aspect. The solid lines show the position of the gastric mill framework ossicles (A, B, J, H and G) after the anterior muscle (M1) and posterior muscle (M2) have contracted, while the dotted lines show their position in the resting state before the muscles have contracted. In the resting state, ossicles B and ossicles H are angled upwards and inwards in relation to ossicles J. It is because of this that ossicles J are pulled upwards and inwards when the framework is lengthened by the contraction of the muscles. The dorsal and medial movements of J push the dorso-medially facing grinding surfaces of the lateral teeth against the ventro-laterally facing grinding surfaces of the dorsal tooth. In addition, there is also a lateral muscle which helps to push the lateral teeth against the dorsal tooth. This muscle is attached at one end, to the dorsal outer edge of ossicles J (Fig. 1 (ii)) and at the other, to the ventral edge of the cardio-pyloric valve (Q—Fig. 1 (ii)). When it contracts it pulls the dorsal outer edge of ossicle J down, so that the inner edge, on which the lateral tooth is situated, is forced up against the anteriorly moving dorsal tooth. The dorsal points of ossicles K (Fig. 1 (ii)) act as fulcra for the pivoting of ossicles J and also prevent the lateral muscle from simply pulling ossicles J and the cardio-pyloric valve Q towards each other. The contraction of the three above-mentioned muscles thus causes the grinding surfaces of the dorsal tooth and the lateral teeth to be brought together and the dorsal tooth to move forwards between the lateral teeth.

A different set of muscles is responsible for returning the dorsal tooth to its original position. These muscles are attached at one end, to the anterior edge of ossicle A (Fig. 1 (ii)) and at the other, to ossicles G, H and J (Fig. 1 (ii)). Their contraction slides the dorsal tooth back until its posterior margin lies slightly behind the posterior margin of the lateral teeth. At the same time the muscles also shorten and widen the gastric mill framework, thereby moving the grinding surfaces of the dorsal and lateral teeth apart. The dorsal tooth is then in a position to be pulled forwards again. It is this forwards and backwards movement of the dorsal tooth over the lateral teeth that grinds the food. This movement is not, however, simply a straight backwards and forwards motion. Because ossicle A, suspended by ossicle

F (Fig. 1 (ii)), swings between an arch formed by ossicle G and ossicles H (Fig. 1 (ii)), the path followed by the dorsal tooth is convex ventrally. This results in an increased shearing action between the dorsal tooth and the lateral teeth and probably leads to a more efficient grinding action.

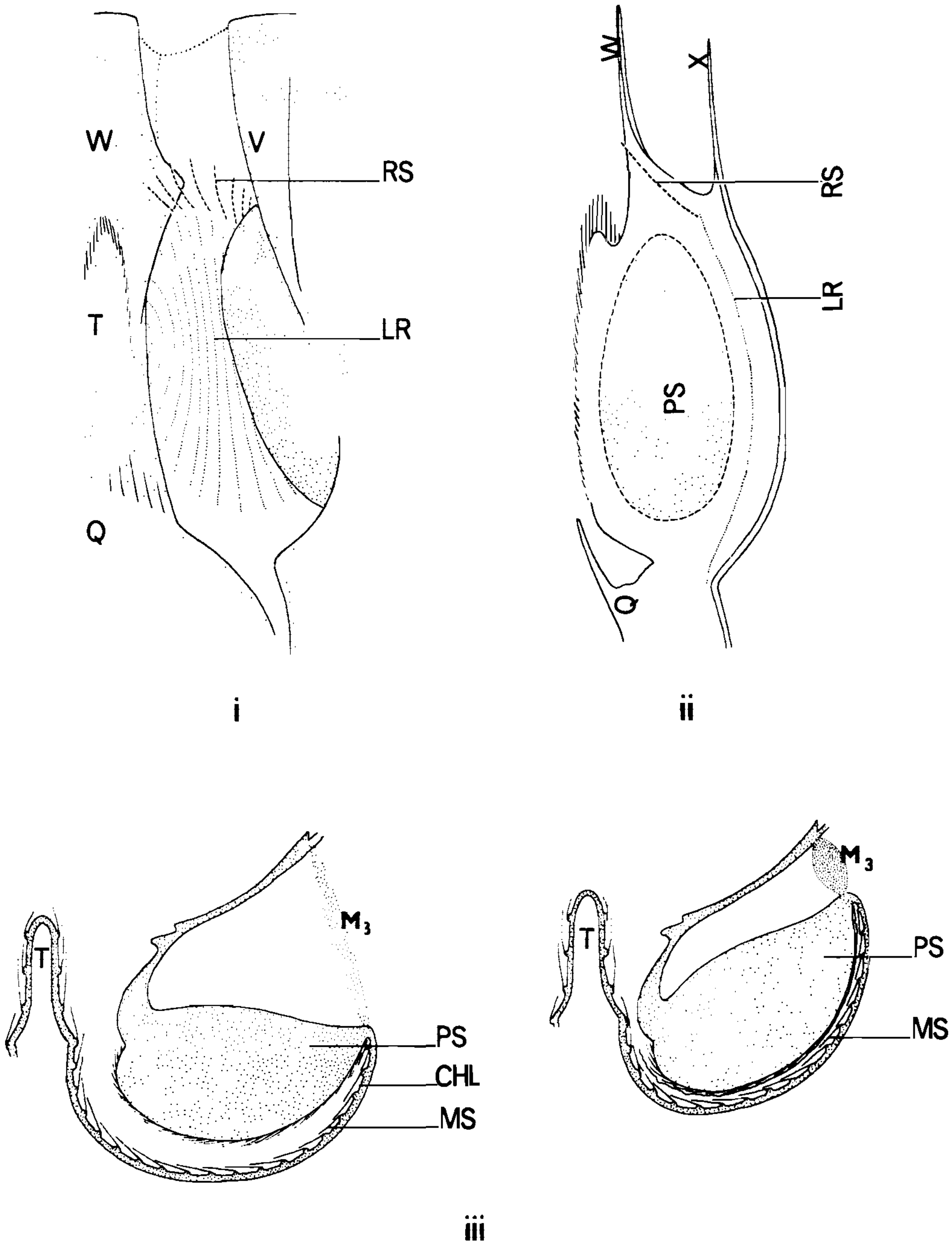
The ventral half of the cardiac-stomach has a series of muscles enveloping its wall. When they contract simultaneously, they decrease the size of the cardiac-stomach and thereby squeeze the food up towards the gastric mill and eventually into the pyloric-stomach. Extrinsic muscles attached to the carapace wall can dilate the stomach again.

Function of the filter (*Fig.* 2)

In Figure 1 (i) the filter was shown diagrammatically as the region Z, into which the ventro-lateral groove (VLG) leads. Figure 2 (i) is a detailed drawing of the dorsal view of the left filtering apparatus. The filter has been opened by pulling folds W and V (Fig. 2 (i) and Fig. 1 (i)) laterally away from each other. On the ventral surface of the filter (which is a continuation of the ventro-lateral groove) there are parallel longitudinal ridges (LR—Fig. 2 (i)) with channels between them. A row of fine setae, originating from each longitudinal ridge, cover the adjoining channel and overlap the row of setae of the next ridge. The overlapping rows form a mat of filtering hairs (Plate 1). At the posterior end of the longitudinal ridges a wall of rods and setae (RS—Figs. 2 (i) and 2 (ii)) guards the entrance to the posterior ventral pyloric-opening, which lies between W and X (Fig. 2 (ii)). (In Figure 1 (i) the wall of rods and setae (RS) are shown diagrammatically; the longitudinal ridges and their setae are not shown.) As can be seen in Figure 2 (ii), the channels, under the mat of filtering seate, are confluent with the posterior ventral pyloric-opening (between W and X) and, therefore eventually lead into the digestive gland, whereas the space above the filtering mat, is confluent with the posterior dorsal pyloric-opening (above W) and, therefore, eventually leads into the hind-gut. A bulbous fold of membrane, the filter press (PS—stippled area, Fig. 2 (ii)) fits on top of the mat of setae.

The filter is operated by a muscle (M3—Fig. 2 (iii)), and functions in the following way. The muscle originates from the external lateral wall of the pyloric-stomach and is inserted on the dorso-lateral edge of the filtering apparatus. When it is relaxed (Fig. 2 (iii)—left drawing) fine particles and liquids can pass from the ventro-lateral grooves into the space between the press (PS) and the mat of filtering setae (MS). When it contracts (Fig. 2 (iii)—right drawing) it raises the lateral edge of the filtering apparatus, thereby causing the filtering setae and the press to come together. This action squeezes liquids through the mat of setae into the longitudinal channels below. From here the liquids flow backwards along the channels and through the posterior ventral pyloric-opening into the digestive gland. Fine particles, left on the mat of setae, also move posteriorly, but are deflected up by the wall of rods and setae towards the posterior dorsal pyloric-opening and into the hind-gut.

The paths taken by the food through the fore-gut can now be summarised by referring back to Figure 1 (i). Food, entering through the oesophagus (at lower left), is pushed up to the gastric mill by constrictions of muscles enveloping the wall of the cardiac-stomach. Here the food is ground to a pulp by the shearing movements of the dorsal tooth (posterior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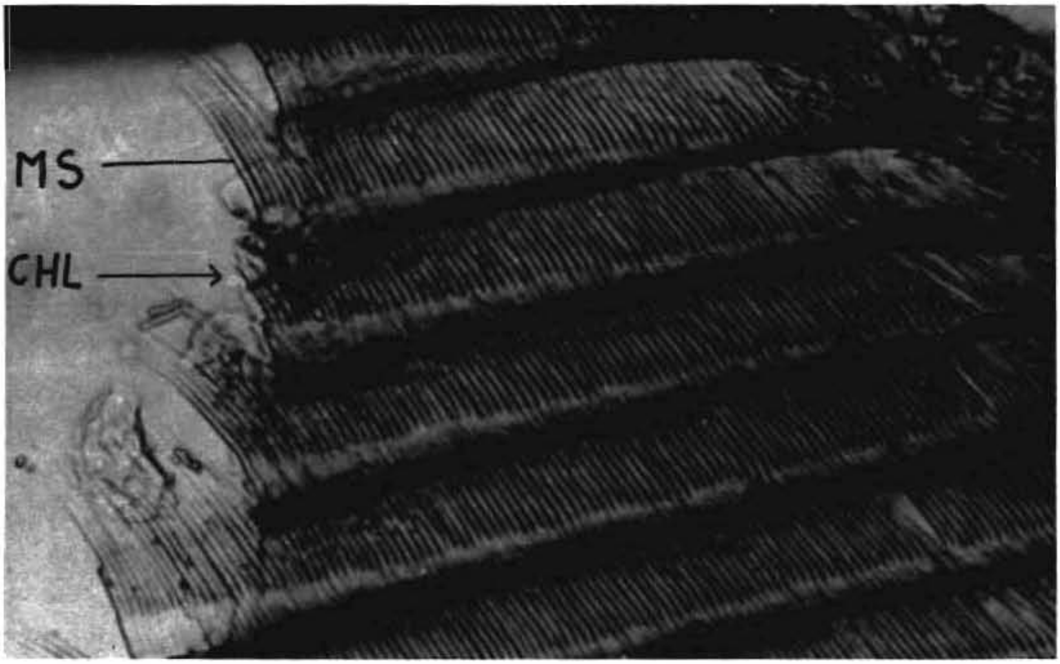

PLATE I
Photograph of the filtering mat of setae (MS). The channels formed between two longitudinal rods are pointed out (CHL). Although the photograph gives the impression that the setae from one longitudinal ridge pass below the next, the setae actually overlie the ridges.

box of ossicle A) against the lateral teeth (posterior box of ossicle J) and is also digested. Particles, too coarse to enter the ventro-lateral grooves (VLG), move straight back (path shown by — ... — ...>) through the posterior dorsal pyloric-opening (PDPO) into the hind-gut. Fine particles and liquids (— · — · >) that can enter the ventro-lateral grooves (VLG), however, pass into the filtering apparatus (Z) where they are separated. Fine particles (— — — — —>) are deflected up to the posterior dorsal pyloric-opening (PDPO) by the walls of rods and setae (RS) and also like the coarse particles, move into the hind-gut. Liquids (· · · · ·>), however, flow through the filter and pass, via the posterior ventral pyloric-opening (PVPO) into the digestive gland. It appears, therefore, that the function of the fore-gut is to reduce food to a liquid state which can be utilised by the animal.

FIGURE 2
Filtering apparatus. (i) Dorsal view of (left) filtering apparatus. Q, T and W are on the median line of the fore-gut. Q is anterior and W posterior. (ii) Longitudinal vertical section of the filtering apparatus. Anterior is towards Q. (iii) Transverse section of the filtering apparatus. T is on the median line of the fore-gut. The muscle that operates the filter is labelled M3. Figs. 2i, 2ii and 2iii are drawn to the same scale. Key to lettering: CHL—longitudinal channels, LR—longitudinal ridges, MS—mat of setae, PS—filter press, Q—cardio-pyloric valve, RS—rods and setae, T—inter ampullary ridge, V—inferior ampullary fold, W—median dorsal lappet, X—median ventral lappet. (The stippled areas in Figs. 2i, 2ii and 2iii indicate the position of the filter press.)

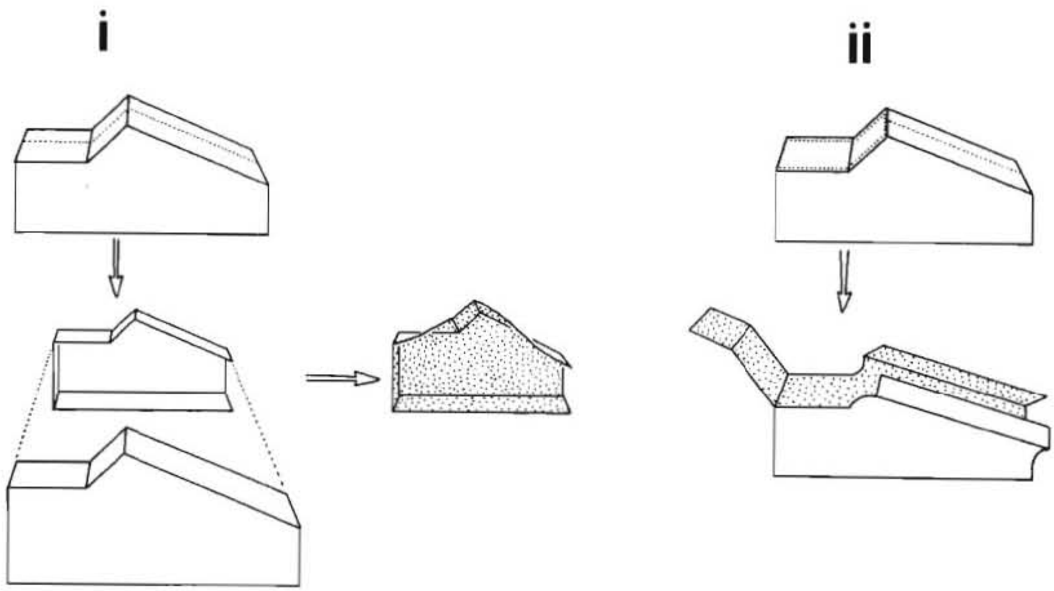

FIGURE 3
Diagrams showing the alternate ways in which the fore-gut was cut open for observation. (i) The stomach is slit longitudinally into right and left halves. The halves are separated from each other in order to show the internal view of the right half (dotted area). (ii) The stomach is slit dorsally. The anterior roof is flapped forwards and the posterior roof opened in order to show the dorsal internal view.

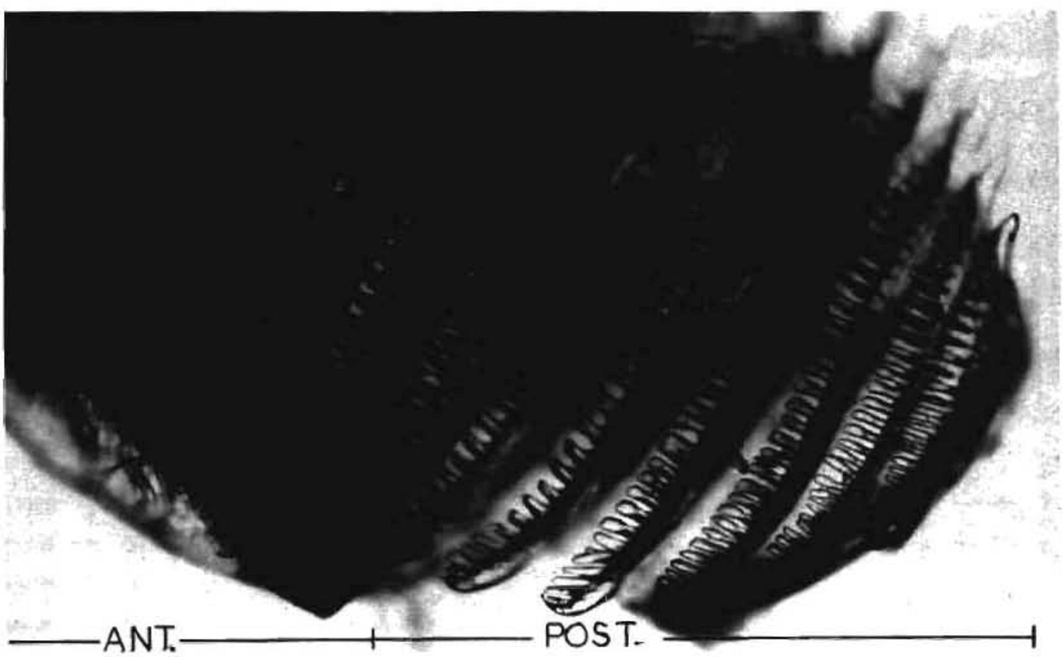

PLATE 2
Photograph of the surface of the lateral tooth of *U. africana*. *Ant.*, anterior half of tooth. *Post.*, Posterior half of tooth.

COMPARATIVE DESCRIPTION OF THE FORE-GUT OF *CYCLOGRAPSUS PUNCTATUS, DIOGENES BREVIROSTRIS* AND *UPOGEBIA AFRICANA*

Methods of Preparing the Material

In order to observe the structure of the stomachs in the three species chosen for the present study, these were dissected out and boiled in 5% KOH for about five minutes to remove all adhering muscle. They were then placed in Methylene-blue eosin alcohol stain for two to four hours, after which they were differentiated in 100% alcohol for about 24 hours. Following this treatment the stomachs were either cut longitudinally into right and left halves (Fig. 3 (i)), or slit open dorsally (Fig. 3 (ii)). Figures showing the internal view of the right half of the stomach (dotted area—Fig. 3 (i)) are numbered 4, 6 and 8, while those showing the dorsal internal view, after the roof has been folded back (dotted area—Fig. 3 (ii)), are numbered 5, 7 and 9.

Comparative Description of the Three Species

In the following comparative description the figures referred to are 4, 5—*C. punctatus;* 6, 7—*D. brevirostris;* and 8, 9—*U. africana.*

In all three species the oesophageal entrance to the cardiac-stomach is guarded by paired setose valves (E) which probably reduce any tendency of food to escape back to the oesophagus. In *C. punctatus* (Fig. 4) and *U. africana* (Fig. 8), the valves are evaginations from the cardiac-stomach wall and have a swollen appearance. In *D. brevirostris* (Fig. 6), on the other hand, they are smaller and less membranous and the setae are relatively larger.

Rows of comb-like setae arise, in all three species, from ossicles M and N (Figs. 4, 6 and 8) and probably prevent coarse material from entering the ventro-lateral grooves. In *U. africana* ossicle M has an additional comb of stiff, flattened setae.

In *C. punctatus* the wall of the cardiac-stomach, antero-ventral to ossicle D, is slightly thickened and bears posteriorly projecting setae. In *D. brevirostris*, in the same position, there are a pair of shield-like plates each with 8 to 10 fairly stiff setae, whereas in *U. africana*, the areas are covered by many soft hairs. These structures are probably homologous, but their function is unknown.

The dorsal tooth and the lateral teeth of the gastric mill differ in the three animals. In *C. punctatus* the dorsal tooth consists of two hardened transverse ridges. The lateral teeth carry a row of equally hardened knobs, which diminish in size posteriorly until they merge into a straight cutting edge. In *D. brevirostris* all the teeth are hardened. The dorsal tooth consists of a single knob, but the lateral teeth have a series of transverse grinding edges. In addition, all the teeth show a surface reticulation. The teeth of *U. africana* are markedly different. On their grinding surface there are transverse ridges which in turn bear anteriorly pointing protuberances (Plate 2); between the ridges and beneath the protuberances there are tunnels. The gastric mill teeth of *U. africana* probably have a squeezing rather than a grinding function. Liquids and very fine particles that are squeezed out of the food pass through into the tunnels below the protuberances. In the posterior half of the lateral tooth the liquids flow directly down from the tunnels into the ventro-lateral grooves. In the anterior half, however, the liquids are channeled back by a ridge (near the letter K—Fig. 8) to the

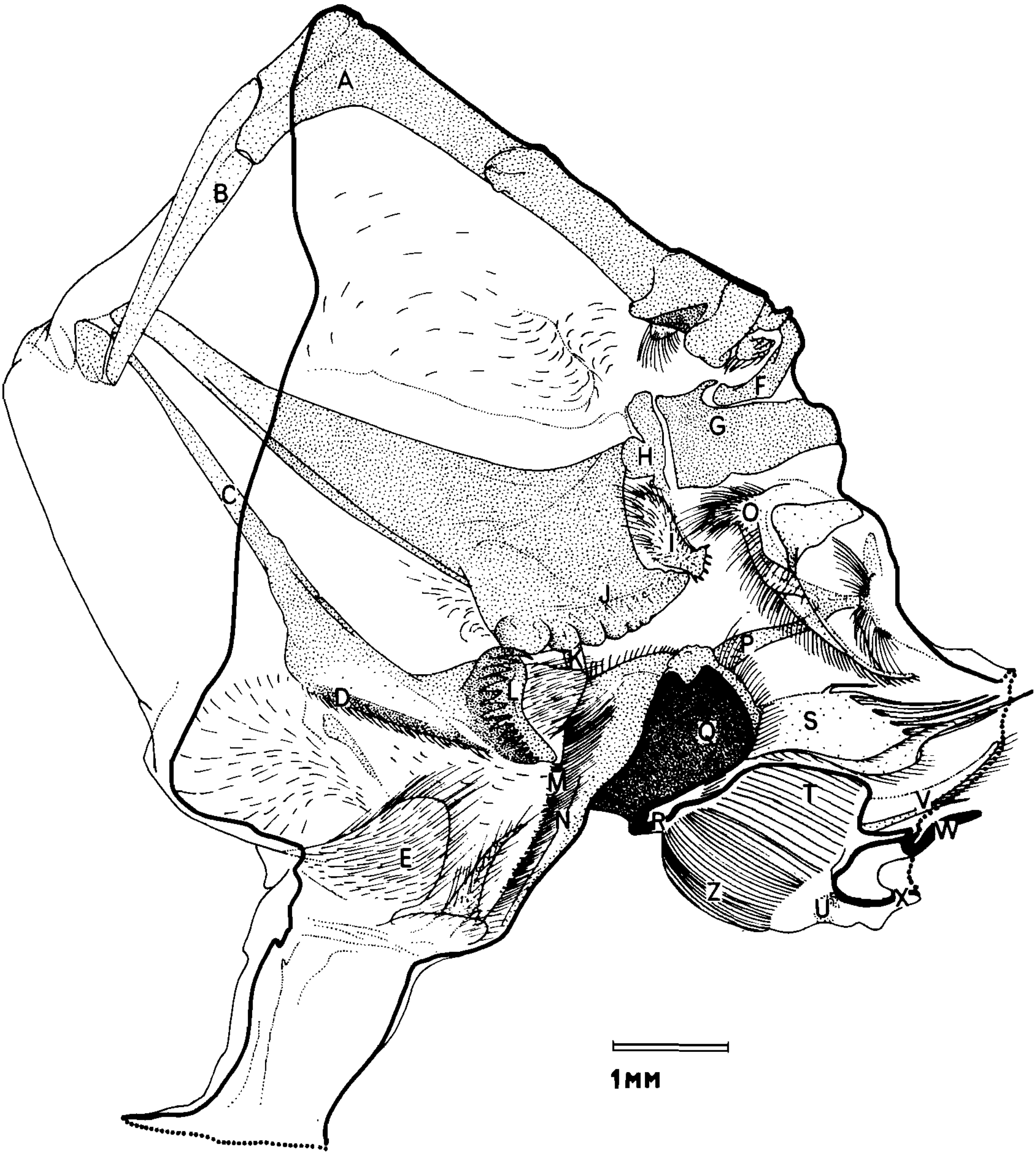

FIGURE 4

C. punctatus. Lateral internal view of the right half of the fore-gut (see Fig. 3i). The darker outline indicates the median line — ossicle A is thus cut in half. Key to lettering: A—urocardiac ossicle, B—pterocardiac ossicle, C—prepectineal ossicle, D—lateral cardiac plate, E—lateral valves of oesophagus, F—propyloric ossicle, G—pyloric ossicle, H—exopyloric ossicle, I—posterior zygocardiac ossicle, J—zygocardiac ossicle, K—sub-dentary ossicle, L—pectineal ossicle, M—posterior pectineal ossicle, N—inferio-lateral cardiac ossicle, O—lateral cardiac pyloric valve, P—lateral pyloric ossicle, Q—cardio-pyloric valve, R—anterior supra ampullary ossicle, S—supra-ampullary fold, T—inter ampullary ridge, U—posterior supra ampullary ossicle, V—inferior ampullary fold, W—median dorsal lappet, X—median ventral lappet, Y—median supra ampullary ossicle, Z—ampullary, or filter, region.

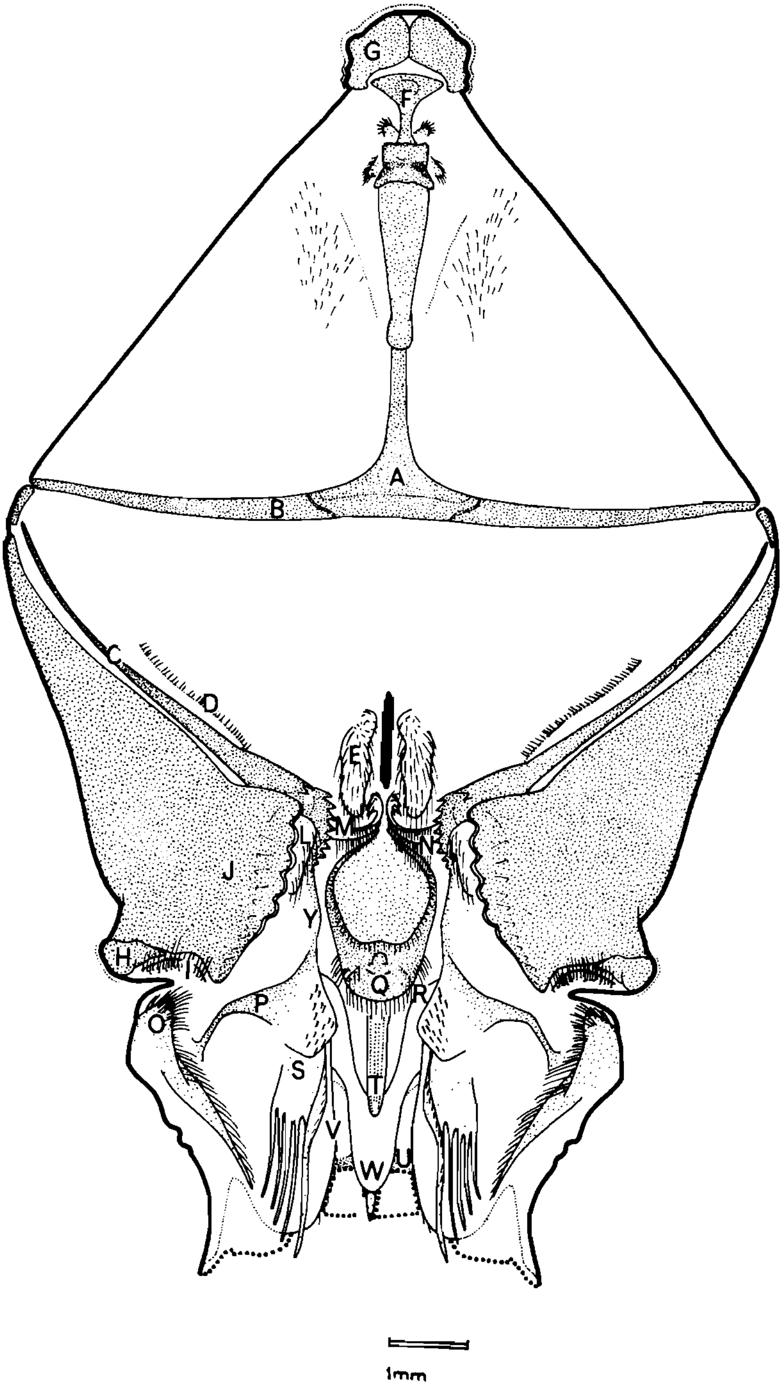

FIGURE 5
C. punctatus. Dorsal internal view of the fore-gut (see Fig. 3ii). The fore-gut was cut open on the darker outline. Ossicles G were originally linked to ossicles H. Key to lettering: see Figure 4.

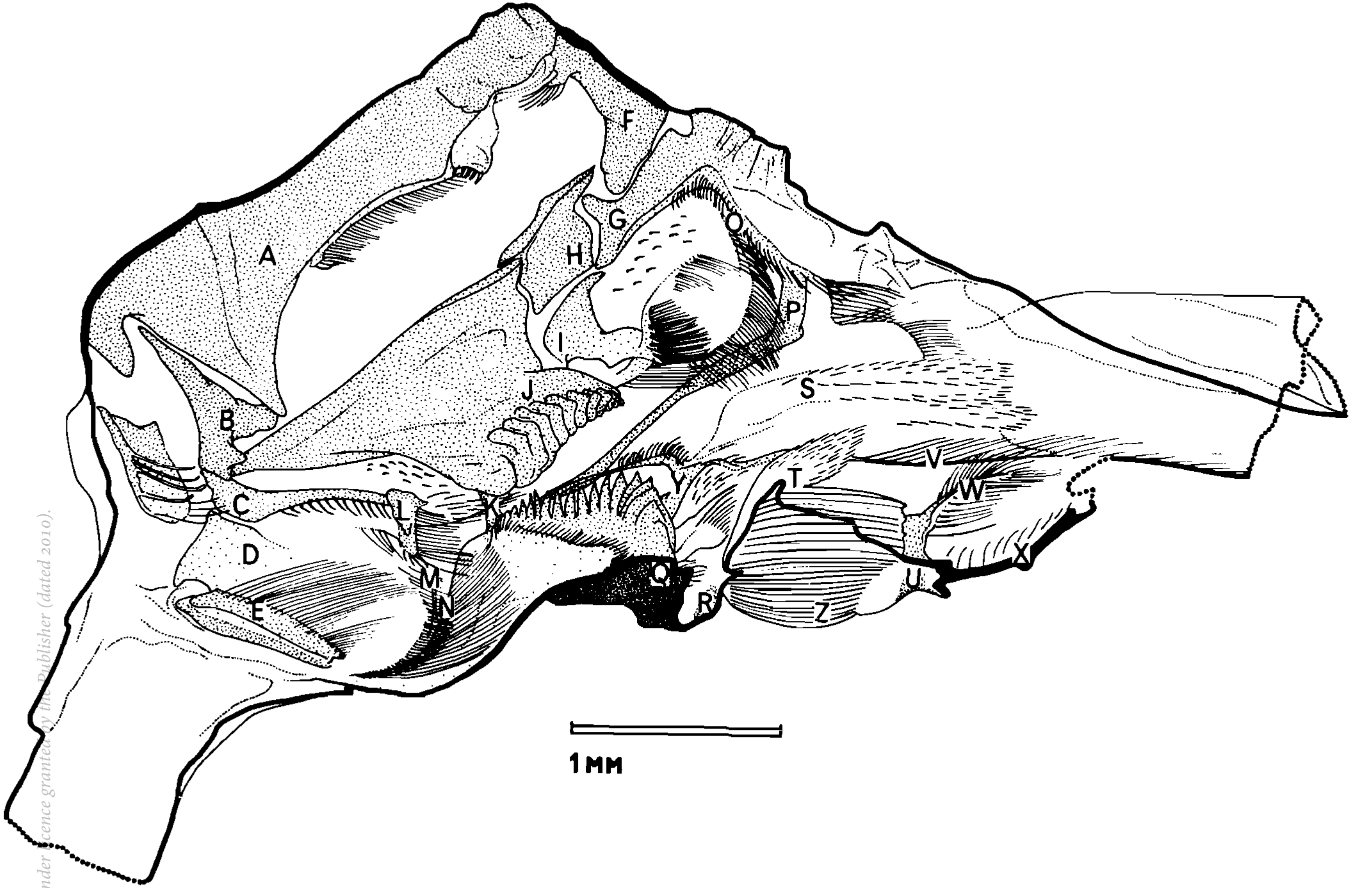

FIGURE 6
D. brevirostris. Lateral internal view of the right half of the fore-gut (see Fig. 3i). The darker outline indicates the median line — ossicle A is thus cut in half. Key to lettering: see figure 4.

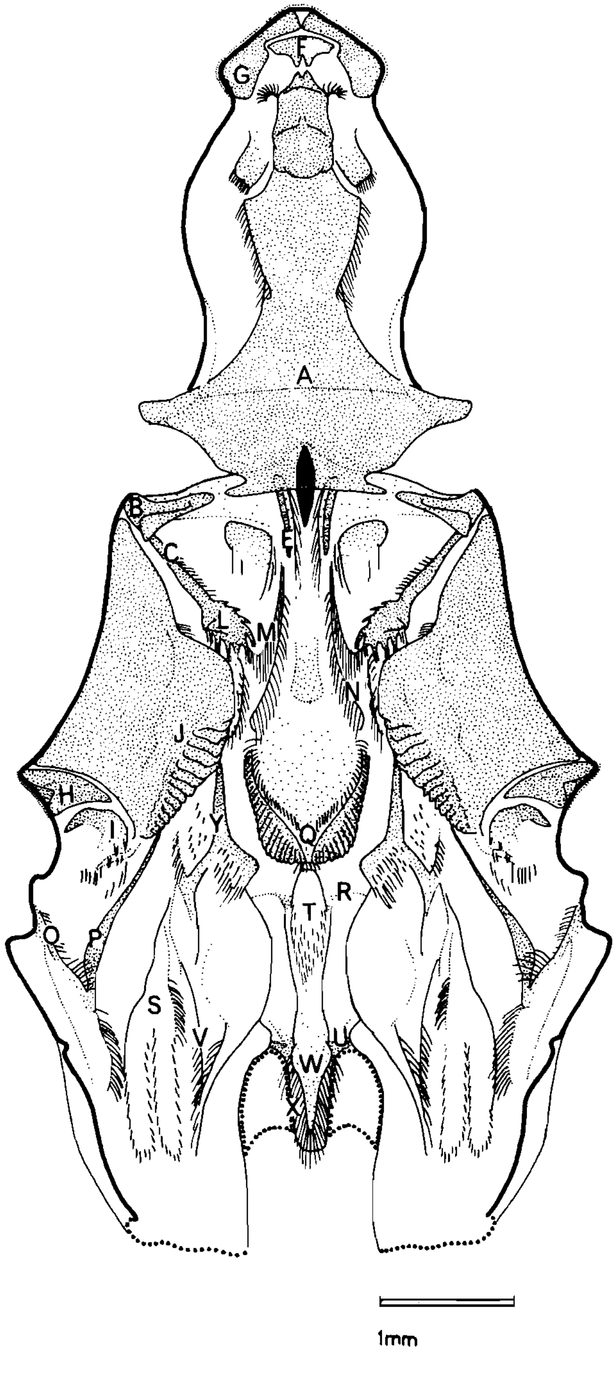

FIGURE 7

D. brevirostris. Dorsal internal view of the fore-gut (see Fig. 3ii). The fore-gut was cut open on the darker outline. Ossicles G were originally linked to ossicles H. Key to lettering — see figure 4.

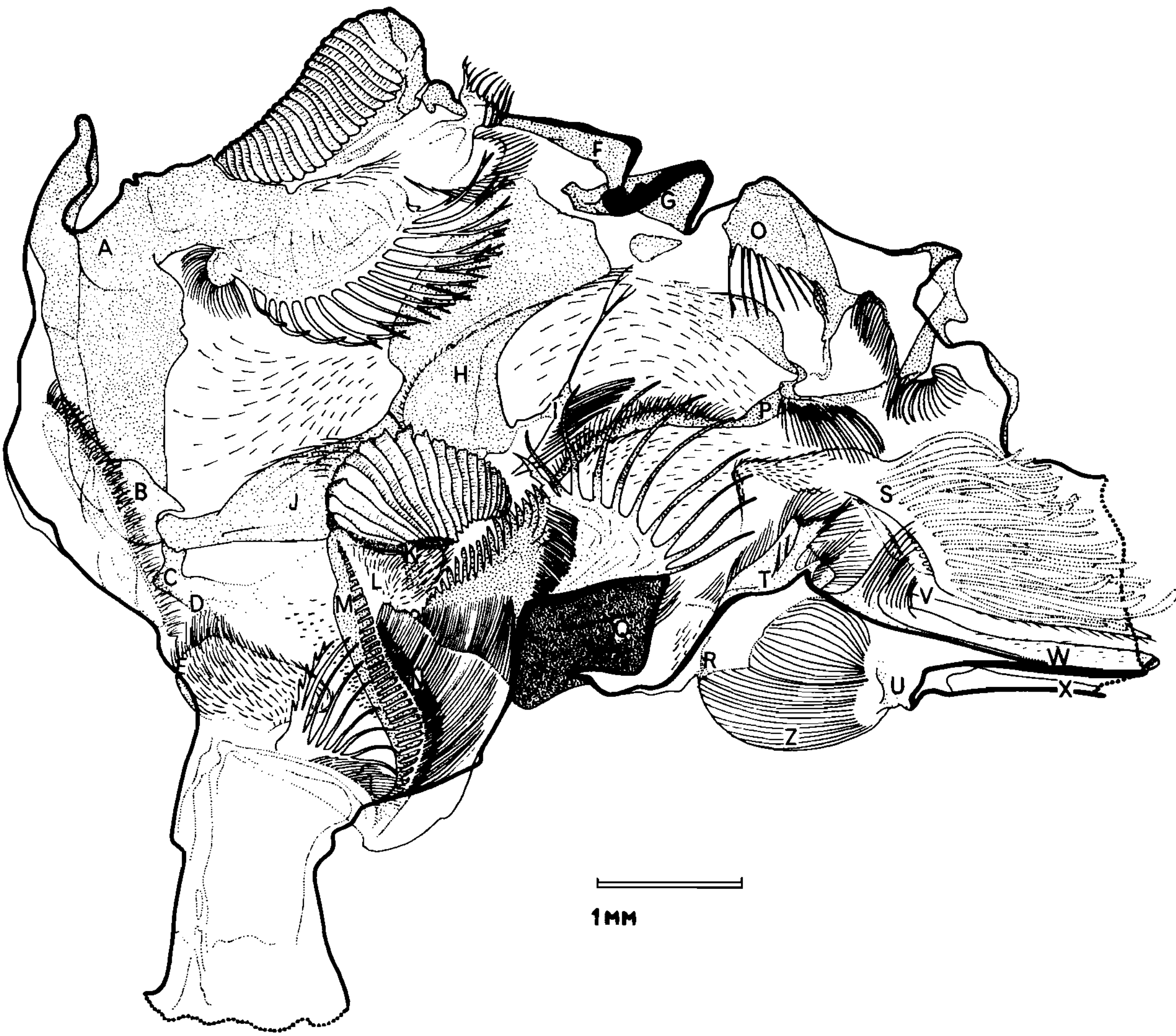

FIGURE 8
U. africana. Lateral internal view of the right half of the fore-gut (see Fig. 3i). The darker outline indicates the median line — ossicle A is thus cut in half. Key to lettering — see figure 4.

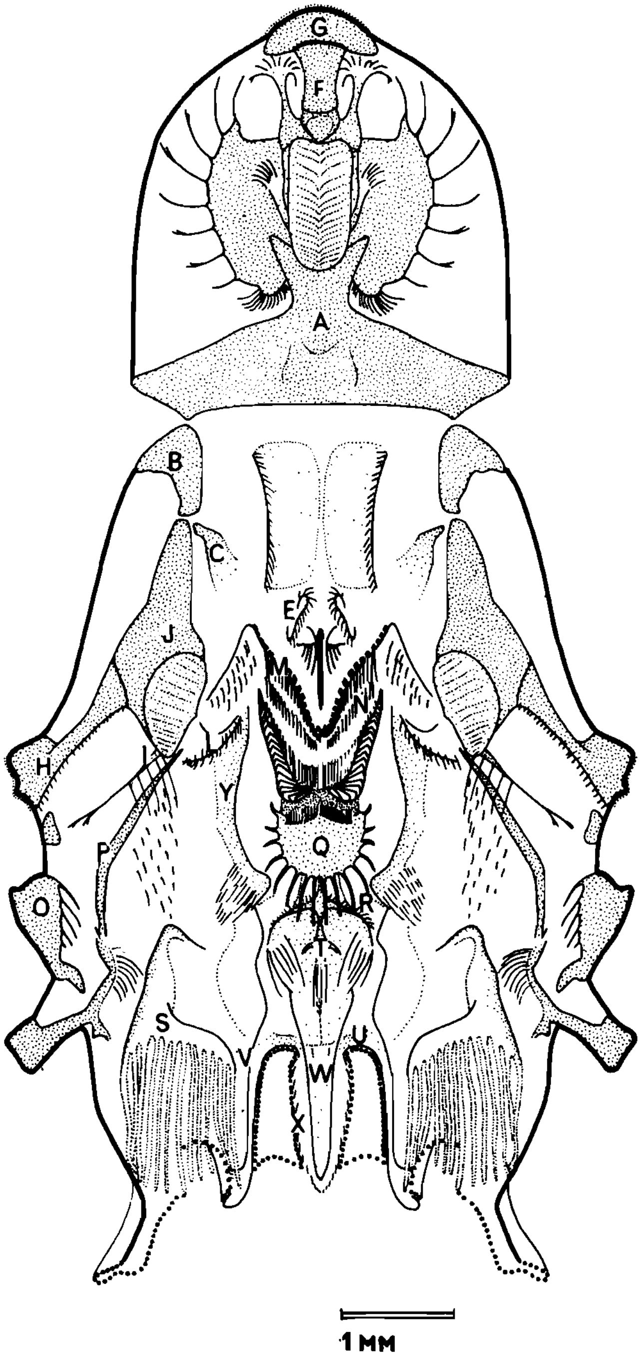

FIGURE 9

U. africana. Dorsal internal view of the fore-gut (see Fig. 3ii). The fore-gut was cut open on the darker outline. Ossicles G were originally linked to ossicles H. Key to lettering — see figure 4.

median part before flowing off the tooth. If this ridge were not present, liquids in the anterior half of the tooth would pass back to the cardiac-stomach and would not enter the ventro-lateral grooves.

On either side of the median ossicle A of all three animals there are tufts of setae; a posterior pair at the junction of ossicles A and F, and an anterior pair. If the dorsal tooth is brought down and positioned between the lateral teeth (as in the living animals), the anterior tufts are suspended over the dorsal surface of ossicles J. With the back and forth movements of the dorsal tooth these tufts will move in unison. Since the setae of the tufts are curved posteriorly, they probably brush food into the gastric mill. The posterior pair of tufts also project backwards and probably help to move food back into the pyloric-stomach. In *U. africana* there is an additional plate with branched bristles between posterior and anterior tufts. This bears minute knobs on its ventral surface. Although the knobs, rubbing on the dorsal surface of ossicles J, could be used for grinding purposes, the plate seems too soft for such a function.

There are lateral accessory teeth on ossicle L, which probably assist in preventing food escaping anteriorly from the gastric mill. In *C. punctatus* (Fig. 4) they consist of an anterior toothed portion which is calcified and a posterior setose portion which is membranous. A similar arrangement exists in *D. brevirostris* (Fig. 6) except that the anterior portion has flattened setae. The lateral accessory teeth of *U. africana* (Fig. 8) consists only of a setose membranous portion.

The posterior dorsal pyloric-opening (above W and V—Figs. 4, 6, 8) is unobstructed except for the supra-ampullary fold S. This fold differs in the three animals. In *C. punctatus* it consists of a membranous plate with seven or eight posterior filaments, whereas in *D. brevirostris* it is merely a membranous fold that gives rise posteriorly to three cylindrical hairy projections. In *U. africana* three arms originate from the fold S and give rise to many pubescent cylindrical projections, pointing back towards the hind-gut. Because the filaments of *C. punctatus* and the cylindrical projections of *D. brevirostris* and *U. africana*, all lie in the posterior dorsal pyloric-opening, they may act as valves to prevent food returning to the pyloric-stomach from the hind-gut.

A series of bristles, or teeth, occur on the anterior dorso-lateral edge of the cardio-pyloric valve Q. These may prevent large food particles escaping posteriorly before they have been ground to a pulp in the gastric mill. *C. punctatus* has short stiff bristles, *D. brevirostris* teeth and *U. africana* flattened bristles. In addition, *U. africana* has 16 long projections arising from the posterior dorso-lateral edge of the cardio-pyloric valve Q. They probably help to keep coarse matter from entering the ventro-lateral grooves.

Posteriorly projecting setae are present on ossicles O and P to ensure that food only moves backwards from the pyloric-stomach to the hind-gut. There are less setae in the stomach of *C. punctatus* than in the stomachs of either *D. brevirostris* or *U. africana*. The setae of *C. punctatus* also tend to be short and stiff, whereas the setae of *D. brevirostris*, in contrast, are relatively long. In *U. africana* they are either short and fine, or when long, pubescent.

The filters of the three animals are basically similar in that they all consist of longitudinal ridges and channels, a mat of filtering setae and a press. The longitudinal ridges in the filter of *U. africana*, however, are only ·015 mm apart as compared to ·03 mm and ·02 mm for *C. punctatus* and *D. brevirostris* respectively. *U. africana* thus has the finest filter of the three species.

DISCUSSION

As was mentioned in the introduction, the diets of the animals differ. *C. punctatus* is a general scavenger eating coarse material, *D. brevirostris* is a filter feeder eating finer material and algae, and *U. africana* also a filter feeder eating only very fine material.

The different diets are reflected by the morphological differences found in the fore-gut of the three animals. *C. punctatus* has a strongly developed crushing type of gastric mill and large lateral accessory teeth to deal with coarse food particles. The pyloric hind-gut valves, originating from S, are simply membranous filaments which are quite adequate for preventing coarse material from returning to the pyloric-stomach. *D. brevirostris* also has a well-developed gastric mill to deal with reasonably coarse food particles, but in addition, the surface of the dorsal tooth and the lateral teeth is reticulated so that finer foods such as algae can also be dealt with. The pyloric hind-gut valves, originating from S, fill up the posterior pyloric-opening more completely than do those of *C. punctatus* and can, therefore, prevent both coarse and fine material returning from the hind-gut. Setae found in the stomach of *D. brevirostris* are also longer than those of *C. punctatus* probably to deal with the finer material eaten. The stomach of *U. africana* is specialised to deal with very fine material. The gastric mill squeezes rather than grinds the food. Because of the structure of the teeth, the process of separating liquids from solids already starts in the gastric mill; this mill can almost be considered as a primary filter. The supra-ampullary fold (S) contains many pubescent cylindrical pyloric hind-gut valves, which would be effective in keeping very fine material from returning to the pyloric-stomach. In contrast to the other two species, setae in the fore-gut of *U. africana* are generally more numerous, finer and often pubescent. They probably help to keep the very fine particles and liquids separate.

The filters of all three species differ only slightly from one another, probably because they deal only with liquids and fine particles produced in the gastric mill and are, therefore, independent of the original food taken in. The filter of *U. africana* is, however, finer than the filters of the other two species. Because of this fineness and because the gastric mill itself acts as a primary filter, the fore-gut of *U. africana* is probably very efficient at extracting liquids from the fine particulate matter which the animal eats.

Clear relations, therefore, exist between the food eaten and the structure of the gastric mill teeth, the structure of the pyloric hind-gut valves originating from the supra-ampullary fold S, and possibly also the structure and the number of setae present in the stomach.

SUMMARY

The internal morphology of the stomachs of three decapod crustacea has been investigated.

A general description of the decapod fore-gut is given and the function of gastric mill and filtering apparatus explained. The fore-gut of the three species is compared and the

differences related to the animal's diet. Adaptation to different diets is reflected in the structure of the gastric mill, the structure of the pyloric hind-gut valves, and also the structure and amount of setae present in the stomach. As the filters of the three species deal only with liquids, they are all very similar.

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