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Microanatomical Studies of Dentalium pilsbryi Rehder, 1942 and D. texanianum Philippi, 1848

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MICROANATOMICL STUDIES OF
DENTALIUM PILSBRYI REHDER, 1942 AND
D. TEXASIANUM PHILIPPI, 1848

by

Kenneth R. Bazata

A THESIS
Presented to the Faculty of
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The author wishes also to thank Diane Stevens, former secretary of the Department of Zoology, for undertaking the chore of typing this manuscript.
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INTRODUCTION

Most of the existing work on the Scaphopoda has been limited to taxonomic studies, based largely on shell characteristics. Very little work has been done on the anatomy of the animal.

The literature concerning the Scaphopoda has been reviewed by numerous workers. The first was Pelseneer (1906), followed by Simroth (1923) and Thiele (1931-1935). The most recent comprehensive review has been done by Fischer-Piette and Franc (1960).

All of the early work on Dentalium species was limited to the European species, D. entalis, D. dentale, and D. tarentinum. Studies based on American species were rare prior to 1920.

The early reports of the anatomy of Scaphopoda are, for the most part, limited to descriptions of gross anatomy. Examples of such studies are Deshayes (1825), on D. entalis, and Clark (1849), on D. tarentinum. It was not until later, about 1861, when the microtome and serial sections became widely used, that more extensive work was done on the anatomy of the Scaphopoda.

Lacaze-Duthier (1856-1857) did the first extensive anatomical and histological work on D. entalis. His monograph is so extensive and so well done, that to this day, figures and descriptions in general texts are based on his work. Fol (1889) studied the anatomy and histology of D. dentale. Plate (1892) also studied the anatomy and general histology of D. entalis. Boissevain (1904) studied the anatomy and general histology of D. entalis.
Leon (1895) was the first to present studies of specific aspects of the Scaphopoda. His primary contribution was a study of the histology of the mantle of *D. dentale*. Distaso (1906) studied the histology of the foot, heart, kidney and mantle of *D. entalis*. Gabe and Prenant (1950a, 1950b) studied the epithelium of the radular organ and the connective tissue of *D. entale*. Morton (1959) studied the captacula, alimentary canal, and digestive gland of *D. entalis*.

The eggs and sperm of the Scaphopoda were first figured by Lacaze-Duthier (1857), for *D. entalis*. Arvy (1950) detailed the cycle of oogenesis in *D. entale*. Lacaze-Duthier (1857) was the first to study embrogenesis in scaphopods. He was able to maintain living larvae for as long as 35 days. Kowalevsky (1883) presented a more detailed study of larvae that reached the age of 14 days. There are many recent reports of the early embryogenesis of *Dentalium* sp., but these are concerned primarily with the behavior of the polar lobe in early cleavage.

Burrowing behavior was described by Morton (1959) and by Dinamani (1964) in *D. entalis*. Trueman (1968) described the burrowing behavior of *D. inaequicostatum*. Gainey (1972) studied the burrowing process in *D. eborium* and *D. pilsbryi*, but used the earlier name *pseudohexagonum* for *pilsbryi*.

Morton (1959) studied feeding in *D. entalis* and Dinamani (1964) studied feeding in *D. conspicuum*, but they disagree in their accounts of the process of obtaining food. Gainey (1972), on observing *D. eborium* and *D. pilsbryi* found that feeding involves a combination of the methods described by Morton and Dinamani.
Yonge (1937) described the water currents in the mantle cavity of D. entalis.

The taxonomy of the Scaphopoda was for a long time based on the account of Pilsbry and Sharp (1897-1898). Henderson (1920) was the first recent worker to present an extensive monograph on the East and Gulf Coast species. Emerson (1962) reported on the taxonomy of fossil and living species.

In the course of an investigation of the nature of the heart and kidney of D. pilsbryi, the present author discovered an unexpected configuration of the anatomy of the digestive system (Bazata, 1971). The present report represents an extension of this preliminary study and is the first detailed account of the digestive system in D. pilsbryi and D. texasianum. Comparative descriptions of the siphonal complex, the foot, and the histology of the anterior mantle also are given.
MATERIALS AND METHODS

Specimens of *D. pilsbryi* and *D. texianum* were obtained from the Gulf Specimen Company, Panacea, Florida. The specimens were sent by air freight from Florida. Upon arrival, the animals were transferred to small plastic aquaria (30cm X 16cm X 9cm) containing sand and sea water from the collecting site. The aquaria were maintained at room temperature (22 C) under a photoperiod of 16 hours of light. The sand was 40mm deep; the covering water had a depth of 40mm. Burrowing behavior was observed in these aquaria.

Specimens to be used for serial sections were placed in Bouin's solution, diluted with an equal volume of sea water, 72 hours for fixation and decalcification of the shell and of the foraminiferans within the digestive tract. Narcotization was attempted, using drops of 70% alcohol and propylene phenoxytol, and magnesium sulfate; none of these methods was successful.

For longitudinal sections, entire specimens were embedded in paraffin and were sectioned at a thickness of seven micrometers. For transverse sections, the specimens were cut into two parts before being embedded. The sections were stained with Harris' hematoxylin and with Mayer's hematoxylin. Eosin was used as a counter-stain. Some serial sets were stained with toluidine blue (Gomori, 1952).

Projection tracings of complete series of sections form the bases for reconstructions of foot, radular area, digestive tract, and the siphonal end of specimens representing both species. Balsa wood and illustration board of appropriate thicknesses were used for these physical reconstructions.
RESULTS

The Shell

The specimens of D. pilsbryi studied had an average shell length of 21.6 mm, with an average siphonal diameter of 1.4 mm and an average ventral diameter of 2.8 mm. The thick shell is curved into a slight arc, with nine primary ribs. In many cases the ribs could be counted only at the posterior or siphonal end, due to erosion of the shell below this point. No microscopical striae were observed. The shell is whitish to grey-white in color. In some shells a chimney, a postsiphonal structure, cylindrical in shape and 1-2 mm high, was present. In most cases this chimney was broken off and only the basal remnant could be seen.

The specimens of D. texanianum studied had an average shell length of 11.3 mm, with an average siphonal diameter of 1.1 mm, and an average ventral diameter of 1.9 mm. The shell of D. texanianum as described by Henderson (1920) is 21 mm in length, thick, well curved, hexagonal in cross-section, and a dull grayish white in color. There are six primary ribs and no secondary ribs. A chimney may or may not be present. The data recorded in this study do not support Henderson's description. The shells here studied had nine primary ribs and secondary ribs. The internal anatomy of the D. texanianum specimens on which the present report is based, especially that of the siphonal end, fits the description given by Peterson (1972) for D. texanianum.
The Foot

The foot of *D. pilsbryi* is a complex, muscular organ, essentially cylindrical in shape. Two lateral epipodal processes or flaps are attached at the anterior one-fourth of the foot (Plate I). The foot is covered with a squamous epithelium. Circular muscle fibers lie directly under the epithelial cells; beneath these is a mass of intermingled longitudinal, transverse, and oblique muscle fibers. The longitudinal muscle fibers converge at the posterior end of the foot, forming two major muscle bands, the foot retractor muscles. The foot retractor muscles extend to the dorsal part of the mantle in a region just ventral to the siphon.

*D. pilsbryi* has a small tube-shaped hemocoel space in the center of the foot. This space is most evident in the region of the epipodal processes. The hemocoel space is lined with squamous epithelium.

The foot of *D. texaskanum* can best be described as vermiform in shape. It has no epipodal processes (Plate II). The foot is covered with squamous epithelium. Circular muscle fibers lie directly under the epithelial cells; beneath these is a mass of intermingled longitudinal, transverse, and oblique muscle fibers. The longitudinal muscle fibers converge at the posterior end of the foot, forming two major muscle bands, the foot retractor muscles. The foot retractor muscles extend to the dorsal part of the mantle in a region just ventral to the siphon.

The interior of the foot of *D. texaskanum* contains a large, open cavity which is lined with squamous epithelial cells. Circular muscle fibers lie directly under this layer of cells. The distal end of the
foot has a pore which is surrounded by a sphincter muscle. The cavity of the foot opens directly to the outside. When the foot retracts, the foot retractor muscles provide the primary force, but the distal end of the foot can also invaginate into the interior of the foot cavity in a manner similar to that of a pulmonate gastropod's ocular tentacle.

Burrowing

When *D. pilsbryi* is placed on sand, it slowly extends the foot. The anterior end of the foot flattens dorsoventrally and appears to test the substrate. The animal then pushes the foot into the sand. The foot at this point is at a right angle to the long axis of the shell. The epipodal processes extend and flap back, catching sand during the process. As the foot extends deeper into the sand the epipodal processes repeat their extension and backward flapping. As a result of continued repetition of this process, the shell is pulled into the sand with the convex ventral side up; when the shell is half-buried in the sand, the animal turns itself so that the concave dorsal side is up. The animal continues to bury itself until only the siphonal end of the shell is exposed above the sand.

After living specimens had been in the observation aquarium for an extended period of time, "trails" recording their movements could be seen. The "trails" are furrow-shaped and represent the paths the animals took while searching for food.

When *D. texanianum* is placed on sand, it extends the tubular foot about one-third of the foot's length and tests the substrate with a snake-like movement. When the animal is ready to burrow, the distal end of the foot pushes into the sand and then apparently expands to
form an anchor. As a result of this action and contraction of the foot retractor muscles, the shell is pulled into the sand. As the foot continues to push into the sand, the shell is brought up to a slight angle and is pulled partly into the sand. This process is repeated until the shell is completely buried, except for the siphonal end. The animal turns the shell during burrowing so that the concave dorsal side is up.

Anterior Mantle

The anterior region of the mantle of *D. pilsbryi* has a thickened area that forms a ring extending completely around the mantle. The ring is somewhat triangular in cross section and consists of a hyaline matrix in which nuclei are located in cavities (Plate III). The matrix is similar in appearance to that of vertebrate hyaline cartilage.

*D. texanianum* also has a thickened ring near the anterior edge of the mantle (Plate IV). The cells of this ring are highly vacuolated. The larger vacuoles at the anterior end of the ring are filled with a substance which appears to be mucoid in nature. The vacuoles become progressively smaller posteriorly. The smallest vacuoles were empty in those specimens which were sectioned.

Siphon

The siphonal end of *D. pilsbryi* has a valve structure (Plate V). Two flaps, adjacent to each other, and V-shaped in section, are located on the dorsal side of the animal, and one such V-shaped flap is located on the ventral side. The valves interdigitate to prevent water flow, or separate to permit water flow.
Hemocoel spaces are found at the bases of the valves. A mass of matrix and cells resembling the "cartilage" of the anterior mantle wall surrounds the area just below the siphon. This mass is not as extensively developed as is the anterior mantle "cartilage."

The siphonal end of *D. texanum* also has a valve apparatus (Plate VI). The valves are semilunar in shape on the dorsal and ventral sides of the animal. The dorsal valve is larger than the ventral valve. When the valves are closed, their free edges overlap to form a seal. When the valves are open, they are folded ventrally. Hemocoel spaces are found at the bases of the valves. A group of vacuolated cells is located dorsal to the base of the siphon. The vacuoles of the cells are filled with a mucoid substance. Although similar to the cells of the anterior mantle ring, they are not as extensively developed as are those of the anterior mantle ring.

**Digestive System**

The digestive tract of *D. pilsbryi* begins with the proboscis, which lies on the dorsal side of the foot. The proboscis consists of three major regions: a central tube and two lateral pouches. The mouth opening lies at the terminal end of the proboscis. The mouth leads to the central tube, which goes directly to the radular cavity, entering at the dorsal anterior surface of the radular complex. The lateral pouches are in communication with the central tube. The pouches are filled with waste products similar to those observed in the rectal area.

The proboscis is a highly extensible organ. Two *D. pilsbryi* which were dissected had foraminiferans (*Elphidium* sp.) in the proboscis.
cavity. The proboscis without food material averages 0.1 mm in diameter; the foraminiferans averaged 0.8 mm in diameter. The foraminiferans were aligned in a row, causing the proboscis to have a beaded appearance.

The salivary glands are located on either side of the proboscis and empty into the radular cavity.

The wall of the radular complex is highly muscular and encloses the jaw and radula. The macerated food enters the foregut from the left side of the radular complex. The foregut is a highly convoluted, small tube, and leads to the midgut. The midgut widens and makes two simple loops. At the beginning of the midgut a duct from the kidney joins the digestive tract. The midgut gives off two blind pouches at approximately one-third and two-thirds of the midgut length. The midgut becomes a broad pouch just before crossing the transverse muscle septum. The midgut constricts, crosses the transverse muscle septum, and joins the stomach.

The stomach is a pouch-like organ into which the digestive gland products empty by way of two broad openings located in the mid-region of the stomach. Upon leaving the stomach the digestive tract constricts, crosses the transverse muscle septum and becomes the hindgut or rectal area.

The hindgut or rectal area is a large, lobed, flattened structure which holds the food materials received from the stomach. The hindgut enters the radular sac at the anterior dorsal side, near the point of entry of the proboscis (Plate VII). Fecal material apparently leaves the animal by way of the proboscis.

The digestive tract of D. texasianum begins with the proboscis, which lies on the dorsal side of the foot. The mouth is at the anterior
end of the proboscis. A central tube extends from the mouth and opens
directly to the radular cavity, entering at the dorsal anterior surface
of the radular complex. Two large pouches lie lateral to the central
tube and communicate with the central tube through slit-like openings.

The wall of the radular complex is highly muscular and encloses
the jaw and radula. The macerated food enters the foregut from the left
side of the radular complex.

Salivary glands are located on either side of the proboscis and
empty into the radular cavity.

The foregut is a small tube which parallels the rectal area for a
short distance, then widens and loops back down toward the radular sac
to the midgut. The midgut extends back toward the posterior end and
widens to form a small pouch. From the pouch the midgut makes a long,
simple loop located between the foot retractor muscles, and enters the
stomach. A duct from the kidney joins the midgut just before it reaches
the stomach.

The stomach is a pouch-like organ. The digestive gland products
empty into the stomach near its mid-region. Upon leaving the stomach
the digestive tube narrows and enters the hindgut or rectal area.

The rectal area is a large, triangular region which serves as a
receptacle for the products leaving the stomach. The rectal area enters
the radular sac at the anterior dorsal side, near the point of entry of
the proboscis (Plate VIII). The fecal material apparently leaves the
animal by way of the proboscis.
Kidney-Heart Region

The so-called heart and kidney lie as adjacent organs, in *D. pilsbryi*, just posterior to the transverse muscle septum. The heart consists of a meshwork of loosely connected muscle fibers. No blood vessels were observed in association with the heart. The kidney is a vacuolated, sac-like organ with a small duct meandering through the tissue. A small duct leaves the kidney, crosses the transverse muscle septum, and enters the digestive tract at the beginning of the midgut.

A papilla was found on the mantle, adjacent to the heart-kidney region. The pore of this papilla connects the space surrounding the heart and kidney with the posterior mantle cavity.

A heart structure is not evident in *D. texanianum*. The kidney is located adjacent to the stomach. The kidney is an ovoid organ with a central duct. This duct emerges and enters the midgut just anterior to the stomach.
DISCUSSION

*Dentalium pilsbryi* and *D. texianum* are two scaphopod species which are not readily distinguishable on the basis of shell characters, but which exhibit distinct differences in anatomy. Contrary to the classic shell descriptions, which indicate nine primary ribs and secondary ribs for *D. pilsbryi* and six primary ribs and no secondary ribs for *D. texianum*, both species in the series studied had both primary and secondary ribs. Peterson (1972), reporting on *D. texianum*, indicated that there is a variation of shell characters. He reported that the number of primary ribs varied from five to eight and that secondary ribs were found on many of the specimens collected. Kraeuter (personal communication, 1972) indicated that the *D. pilsbryi-D. antillarum* group is a very difficult one, as it seems to overlap the *D. texianum-D. gouldi* complex at times. The present study indicates that there is such an overlapping in shell characters of *D. pilsbryi* and *D. texianum*.

Although the shells of the two species are not distinctly different, one can use the differences in foot characteristics to make a positive separation (Plate IX). The foot of *D. pilsbryi* is a highly muscular, cylindrical organ with two epipodal processes. Essentially all reports of the morphology of the foot in species assigned to the Dentaliidae describe a similar morphology. The small pedal hemocoel most likely does not influence the control of the shape and size of the foot as in other species, but probably aids in the control of the epipodal processes.
According to Henderson (1920) the Siphonodentaliidae have a foot that lacks any epipodal processes; it is a slender, vermiform organ, and is expanded at the end into a symmetrical disk with a fluted or indented border. *D. texanianum* has a foot that is similar in basic morphology to that of the Siphonodentaliidae, but the expanded disc at the distal end is not present. Additionally, the shell of *D. texanianum* does not fit in the family Siphonodentaliidae because of its sculpturing. The distinctive feature of the foot of *D. texanianum*, which has been described by Peterson (1972), is the central cavity which opens to the outside. This most likely serves to aid in the hydraulics of foot expansion, and must be an important part of the burrowing process.

Observations on the burrowing process in *D. pilsbryi* support the report of Gainey (1972) on this species. Observations of the *D. texanianum* burrowing process have not been described previously, but the process is similar to that used by *Cadulus* (Davis, 1968). Davis' report is one of the few on burrowing in the Siphonodentaliidae. The conspicuous difference in the burrowing of *D. texanianum* in comparison with that of *Cadulus*, is that the shell of *D. texanianum* is rotated during burrowing so that the concave dorsal surface comes to lie uppermost.

The siphonal valve system of *D. pilsbryi* is similar to that of other species of *Dentalium* described in the classic literature, such as Lacaze-Duthier (1857-1858), Plate (1892), and Boissevain (1904). The valve flaps are three in number, with two on the dorsal side and one on the ventral side. The siphonal valve system of *D. texanianum* is different from that described in other species of *Dentalium* (Peterson, 1972). It consists of two semilunar valves.
Both types of valves must function to let water flow to the mantle cavity for respiration when open, and to stop the water flow when they close. The valves may also be involved, after a slow water intake, in the rapid water ejection, as described by Yonge (1937). Both sets of valves have hemocoel spaces at their proximal ends. These spaces apparently serve in the hydraulic control of the valve system. Both species have support structures. *D. pilsbryi* has "cartilaginous" support elements below the siphon valves and *D. texanianum* has a system of vacuolated cells filled with a mucoid substance, located dorsal to the valve flaps. This support system most likely serves to keep the siphonal end of the animal expanded when the valves are open.

At the anterior end of the mantle both species have a ring-shaped, thickened area. In *D. pilsbryi* the thickened area has an appearance similar to that of vertebrate hyaline cartilage. The thickened area of *D. texanianum* is made up of vacuolated cells filled with a mucoid substance. Fol (1889), Plate (1892), and Boissevain (1904) indicate a "gelatinous ring" in the anterior mantle. Gabe and Prenant (1950b), in a study of *D. entale*, found that the anterior mantle has a ground substance similar to that of vertebrate hyaline cartilage, but that this "cartilage" is more fluid than that of the vertebrates. A probable function of the rings is to provide support for the mantle opening, permitting efficient operation of captacula and foot (Bazata, 1972).

The distinctive vacuolar cells of the supportive ring of the ventral mantle in *D. texanianum* are similar, in routine hematoxylin and eosin preparations, to the cells in the mantle margin and in parts of the reproductive tract of the terrestrial pulmonate, *Cionella lubrica*.
(Gugler, 1974, personal communication). It is tempting to speculate that we have, in Dentalium, and in other molluscs, an evolutionary series representing stages of increasing efficiency in the mechanical refinement of a support system. Turgidity could well be achieved by masses of cells with extensive vacuoles filled with mucoid material. As indicated above, Plate (1892) and Boissevain (1904) recognized the gelatinous nature of the mantle stiffening ring of the species of Dentalium they studied. If the aggregates of vacuolar cells such as are present in the mantle ring of D. texanianum and in the mantle margin and parts of the reproductive tract of C. lubrica represent primitive solutions to the problem of mechanical support, one would expect to find intermediate conditions between the D. texanianum and C. lubrica status and the D. pilsbryi status. The latter presents the classic histological picture associated with vertebrate hyaline cartilage, although Lash (1959), Person and Philpott (1969), and Philpott and Person (1970) reported that the chemical composition differs from that of vertebrate hyaline cartilage. Intensive histochemical studies of a variety of molluscs will be needed to resolve this problem; such studies are beyond the scope of the present investigation.

The digestive system of D. pilsbryi is a rather complex tract. It begins with the proboscis, with its two lateral pouches, and leads to the radular sac. From the radular sac, the digestive tract makes three loops to compress itself in as little space as possible on its way to the stomach. There are two blind pouches branching from the digestive tract, at one-third and two-thirds the length of the tract. The duct from the kidney enters the digestive tract shortly after the tract
leaves the radular sac. The digestive tract widens to a pouch-like area, constricts to cross the transverse muscle septum, and joins the stomach. The hind-gut, or rectal area, leaves the stomach and broadens to form a large pouch. Digestive end-products apparently leave the body through the radular cavity and the proboscis.

A schematic representation of the digestive tract of *D. pilsbryi* is presented in Plate X.

The digestive system of *D. texaskanum* is somewhat simpler than that of *D. pilsbryi*. It begins with the proboscis, with its two lateral pouches, and leads to the radular cavity. From the radular cavity, the digestive tract makes three turns on its way to the stomach. The duct from the kidney enters the digestive tract just before the tract enters the stomach. The digestive tract joins the stomach and the hind-gut or rectal area leaves the stomach, expanding as a pouch over the radular area. Digestive end-products apparently leave the body through the radular cavity and the proboscis.

A schematic representation of the digestive tract of *D. texaskanum* is presented in Plate XI.

The configuration and the functional relationships of parts of the digestive tract exhibited by *D. pilsbryi* and *D. texaskanum* have not been described previously for any scaphopod. Without further intensive investigations and re-investigations of other scaphopods, conclusions concerning the evolutionary significance of the course of the digestive tract in *D. pilsbryi* and *D. texaskanum* cannot be made. Certainly one cannot conclude that one understands the scaphopod digestive tract in terms of generalizations. A comparative study of all species is essential.
The papilla, described above in the account of the circulatory and excretory systems of *D. pilsbryi*, might well be mistaken, in gross dissection, for an anus. Lacaze-Duthier (1857-1858) was the first to assign this function to a similar papilla in this general location and accounts of this presumed function have been carried into modern literature without being re-investigated. It is apparent that serially sectioned material is essential if an accurate interpretation of the internal anatomy is to be given.

The present study emphasizes the need for intensive anatomical investigation of the scaphopods. It is clear that the brief, generalized account routinely given for scaphopods in general texts and, indeed, in the comprehensive, monographic treatments, is inadequate. Future comparative microanatomical studies will form the basis for the subsequent and essential comparative physiological studies. In the interim, we must realize that generalizations concerning the anatomy of scaphopods are, without question, hazardous.
SUMMARY

The foot of *Dentalium pilsbryi* is a cylindrical organ with two epipodal processes. These processes assist in the burrowing activity. The interior of the foot of *D. pilsbryi* includes a small hemocoel cavity which appears to aid in extension of the epipodal processes. The foot of *D. texanianum* is a slender and cylindrical organ which has no epipodal processes. The foot of *D. texanianum* has a conspicuous central cavity which communicates with the exterior by a pore which is provided with a sphincter muscle.

The anterior mantle of *D. pilsbryi* has a skeletal support in the form of a ring of tissue which resembles vertebrate hyaline cartilage. The comparable region of the mantle of *D. texanianum* is supported by a ring of cells with large vacuoles filled with a mucoid substance.

The siphonal end of both species is provided with a valve system. That of *D. pilsbryi* has two dorsal flaps and one ventral flap; that of *D. texanianum* has two single flaps of which the dorsal is the larger.

In both species the digestive tract presents a configuration distinctly different from that previously described for any scaphopod. There is no anus; the terminal gut empties into the radular cavity. In *D. pilsbryi* the midgut includes two blind pouches which are not present in *D. texanianum*. In *D. pilsbryi* there is a transverse muscular septum through which the midgut, the hindgut and the kidney duct pass; *D. texanianum* has no such septum.

In *D. pilsbryi* there is a vesicular "heart" immediately anterior to the kidney. The cavity surrounding these two organs opens to the exterior in a distinct papilla. *D. texanianum* has no such papilla.
LITERATURE CITED


PLATE I

Projection tracing of frontal section of the foot of *Dentalium pilsbryi*. Scale = 0.2mm.
PLATE II

Projection tracing of semi-frontal section of the foot of

*Dentalium texanianum*. Scale = 0.2mm.
PLATE III

Frontal section of anterior mantle region of *Dentalium pilsbryi*.

C - "cartilage", CT - captucula, F - foot. Scale = 0.1mm.
PLATE IV

Semi-frontal section of anterior mantle region of *Dentalium texasianum*. CT - captacula, FH - foot hemocoel, V - vacuolated cells. Scale = 0.1mm.
PLATE V

Siphonal valves of *Dentalium pilsbryi*. Scale = 0.2mm.
PLATE VI

Siphonal valves of *Dentalium texanianum*. Scale = 0.1 mm.
PLATE VI

hemocoel

dorsal valve

ventral valve

oocyte
PLATE VII

Sagittal section of *Dentalium pilsbryi* in radular area. F - foot, G - cerebral ganglion, H - hindgut or rectal area, M - midgut, P - proboscis cavity, R - radular complex. Scale = 0.1mm.
PLATE VIII

Sagittal section of *Dentalium texasianum* in radular area.

Scale = 0.2mm.
PLATE IX

Soft parts of *Dentalium pilsbryi*, left, and *D. texasianum*, right.

F - foot, R - supportive ring of anterior mantle, S - siphon.

Scale = 2mm.
PLATE X

Schematic diagram of digestive tract of *Dentalium pilsbryi*. 
PLATE X

digestive gland duct

stomach

transverse muscle

kidney duct

blind pouches

mid gut

foregut

radular complex

rectal area

proboscis pouch
PLATE XI

Schematic diagram of digestive tract of Dentalium texanianum.