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I hereby recommend that the thesis prepared under my supervision by Samuel R. Magruder
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THE ANATOMY OF THE FRESH WATER PROSOBRANCH GASTROPOD, PLEUROCERA CANICULATUM UNDULATUM (SAY)

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by

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INTRODUCTION

The Pleuroceridae have been known for more than a century, yet there has been but little work done on their anatomy or life history, and since represenatives of this family make up an important part of the fresh water life of the Eastern half of the United States, a study of some phases of their biology seems particularly desirable. In fact, there are very few species of American fresh water prosobranch gastropods whose anatomy or life history is completely known, and there is especially a great need for more information about the Taenioglossate gastropods.

In the present anatomical investigation approximately 720 animals have been dissected with the aid of a binocular dissecting microscope. Serial sections of entire animals and organs or regions have been made for the purpose of corroborating and extending the findings of gross dissections. The study of the microscopic anatomy has been limited largely to elucidating the general anatomy, and in describing structures that may have some taxonomic significance. The minute descriptions of cellular anatomy are not included except in a few cases, as such a study is beyond the scope of this work. It is possible, but not probable, that differences which would be of taxonomic importance might be confined to such minute structures.

Pleuroceridae are streptoneurous gastropods and are placed in the order Ctenobranchiata (Pectinibranchia, Monotocardia) because of the presence of a pectinate gill or ctenidium as the chief respiratory organ. They are placed in the suborder Platypoda owing to the possession of a flat creeping foot. They are assigned to the superfamily Taenioglossa owing to the presence of a taenioglossid radula consisting of three teeth on each side of the median tooth. The Pleuroceridae are placed next to the family Pomatiopsidae and form the last family of the subclass Streptoneura as arranged by Baker ('28).

The animals used in this work were identified as Pleurocera caniculatum undulatum (Say) by Mr. Calvin Goodrich of the University of Michigan Museum of Zoology. However, he says, "it should be understood that, in reality, it is doubtful that it (undulatum) is of subspecific value" (personal communication). The term undulatum is used more as a convenience to separate this from closely related forms, the relationships and values of which have not been completely worked out. To quote Mr. Goodrich again ('22), "The variability of the Pleuroceridae is notorious. Because of this.....the family has been neglected..... That a collection of individuals in the Pleuroceridae may be called a species whose predominant characters are not the predominant characters of another collection of individuals".

MATERIAL

The animals used in this work came from the Licking River at Butler, Kentucky, where all were collected from the same colony of animals at approximately the same place. The Licking River at this point is a shallow stream with a fairly swift current in the main channel. Along the edges are numerous quiet bays or inlets with solid limestone bottoms covered with a muddy ooze in which hundreds of these animals live together with even greater numbers of <u>Lithasia obovata</u> (Rafinesque), a gastropod belonging to the same family. These animals are also found in all other parts of the river bed in less abundance, even in the swiftest currents on gravel bottom.

As far as can be determined from examinations of the contents of the alimentary canal these gastropods are entirely herbiverous, also from the behavior in aquaria, it would seem that their chief diet is vegetal. However, here, as in most American fresh water gastropods, there is little available data on exactly what constitutes the food of these animals.

Nothing is known concerning the breeding activity or eggs of this species. Judging from the five other species of this family in which the eggs have been recorded (Jewel '31, Van Cleave '32, Winsor '33), it is probable that the eggs of <u>Pleurocera caniculatum undulatum</u> (Say) will be found on the under side of algae covered rocks in running water. They will probably be in very small groups of eight to ten eggs enclosed in a convex mass of clear jelly.

GENERAL MORPHOLOGY

The body of the animal is divided into head, foot and visceral mass, as in most gastropods, and is connected to the heavy shell by a large columellar muscle. The mantle, so characteristic of the mollusks, is present and encloses in its cavity certain structures which will be discussed below. Various pallial organs can be seen through the mantle in some cases, depending upon the amount of pigment present. Usually the osphradium can be seen indistinctly on the extreme left side; at its right is located the ctenidium (Fig.), the leaflets appearing as faint transverse lines.

The head is prolonged into a snout which is capable of extreme contraction and expansion. The snout is flattened dorso-ventrally and the greater part of its bulk is composed of muscle tissue. The covering epithelium is of the same type as that which covers the rest of the head and foot. There are many gland cells, most of which are very long and narrow as contrasted with the thick flask-shaped cells of the mantle.

The tentacles have the same color as ~~are colored similar to~~ the snout and are covered with the same type of epithelium. The core of the tentacle is made up of connective tissue and muscle tissue through the center of which runs the large tentacular nerve accompanied by a large blood vessel which is a branch of the cephalic aorta. There is no definite arrangement of the muscles into layers, although the greatest number of longitudinal fibers is found in the center. It is probable that these are used to withdraw the tentacles while the remaining, more or less circularly arranged fibers, with the aid of the blood, are used in extending the organ.

The foot is composed mainly of one large mass of muscle tissue covered by general body epithelium. The pedal muscle mass is continuous posteriorly with the columellar muscle and differs from it in that the fibers of the latter are all parallel. The foot, which forms the main mass of the extruded animal is approximately square in outline and is a dark gray in color. On its posterior dorsal surface the foot bears the small horny operculum.

In section, the sole of the foot is seen to be covered by a thick carpet of medium length cilia borne by the epithelial cells. Beneath the surface and composing part of the ventral epithelium are numerous gland cells which reach greater abundance here than anywhere in the body. There is a wide region just beneath the epithelium which is made up entirely of gland cells. Some of these cells reach the surface but others apparently open by small ducts which are the extensions of cells between the cells composing the epithelium. The abundance of well developed cilia and gland cells indicates that probably they play no small part in the locomotion of the animal (Copeland '19, '22). From observations on the movements of the animal it would appear that locomotion might be due to both muscular and ciliary action, although there is no experimental evidence to support this statement.

The data regarding the *opercula* of the Pleuroceridae seems to be remarkably scarce (Goodrich '22). The operculum of *Pleurocera caniculatum undulatum* (Fig.) is of a reddish brown color and varies greatly as to thickness. It is apparently somewhat degenerate and does not completely close the aperture when the animal withdraws into the shell. The left margin is slightly curved and the right is greatly curved. The apex and base are rounded. The outline varies a great deal because of the wearing away and breaking of the margins. The growth lines are fine and there are from six to eight well marked rest scars. The nucleus is decidedly sunken and is located toward the left posterior side just within the base; it shows no distinct whorls. The area of attachment is a thickened oblong area on the anterior side and is bounded by a heavy ridge.

MANTLE

The *mantle* forms a covering around the animal and on the dorsal side encloses a large cavity in which the organs of the pallial complex are located. The mantle itself is comparatively thin but is bounded anteriorly by a thickened, smooth margin which is slightly recurved to fit against the peristome of the shell. The mantle is covered above and below by cuboidal epithelium, and below also by gland cells which reach a great abundance in some regions, such as ventral to the rectum and in the extreme posterior end of the pallial cavity. The center of the mantle is composed of connective tissue and muscle tissue through which run a large number of blood spaces, which ultimately empty into the afferent branchial sinus.

The <u>osphradium</u> is located on the roof of the pallial cavity just to the left of the ctenidium (Fig.)and is thus directly in the path of the respiratory current. In gross structure it is little more than a low, faintly corrugated ridge which is slightly darker than the surrounding tissue.

Earlier workers and even some of the present workers call this organ an accessory or rudimentary gill. Lacaze-Duthier ('59) was the first to doubt the respiratory nature of this organ and finally came to the conclusion that the organ was sensory in nature, and because of his work it was known as Lacaze-Duthier's organ. Spengel, who made a comparative study of the organ, came to the same conclusion as Lacaze-Duthier and called it the "Geruchsorgane". It was also known as Spengel's organ.

Spengel, speculating as to its function decided that from its position in the pallial cavity near the ctenidium it was an organ for testing the physical and chemical qualities of the water and might possibly aid in selecting food. Bernard ('90) in his anatomical study of the organ supports the view of Spengel. Copeland ('18) working on two species of marine snails conducted experiments which proved, without much doubt, that these snails found food through directed movements resulting from stimulations of the osphradium by odorous material directed to it by the shifting siphon.

In *Pleurocera caniculatum undulatum* the osphradium is located in the pallial cavity immediately to the left of the ctenidium. Due to its position it is in the direct path of the respiratory current. From its structure it would seem impossible for it to have any respiratory value.

In cross section the osphradium is seen as a low flattened ridge, the core of which is composed of the large osphradial nerve and supportive tissue through which run a few blood spaces. The epithelium is composed of three kinds of cells, *viz.*, (1) non-ciliated or sensory cells, (2) ciliated cells and (3) glandular cells. The non-ciliated cells occupy the entire flat top of the organ and parts of the sides and are by far the most abundant type. The ciliated cells are found only on the sides of the ridge, the cilia being very feebly developed. The gland cells are scarce and their distribution is not limited.

The *ctenidium* hangs from the roof of the pallial cavity, its anterior end lying about the midline anteriorly and extending diagonally posterior to the pericardium (Fig.). It is composed of about 110 triangular plates which are attached along the base and have a rounded apex (Fig.). The free sides of the plates are of unequal lengths, the left being longer than the right side (Fig.). The plates are largest in the middle of the ctenidium and decrease in size toward each end. The ctenidium is of the monopectinate type, the plates being attached in a single row along the axis.

In cross section (Fig.)each plate is seen to be covered by a layer of epithelium which in turn covers a thin layer of connective tissue and muscle fibers. In the center of each plate is a blood space through which the blood passes while being aerated. The epithelium, as in the osphradium, is composed of three types of cells, viz., (1) non-ciliated cells, (2) ciliated cells and (3) gland cells, all of which are columnar. Most of the general surface is covered by non-ciliaed cells.

All of the cells lie on a very thin basement membrane in which only a few scattered nuclei can be seen and no cell boundries are visible. Just inside this is a layer of connective tissue and muscle fibers which bound the blood space. A number of these small muscle fibers cross the blood spaces in an oblique fashion. Prashad ('25) in his discussion of Pila globosa says, "Apparently these muscle fibers, by their contraction, draw together the two surfaces of the lamellae thereby reducing the lacunar spaces and forcing the blood from the lacunae into the efferent vessel".

Respiration in this animal is true aquatic respiration for the most part, the blood being aerated in the blood sinuses in the ctenidial leaflets which hang down in the respiratory current. The general current in and out of the pallial cavity can be followed by introducing a small amount of non-toxic coloring matter into the water near the animal.

It is quite probable that a certain amount of respiration occurs over the general body surface. The mantle is extremely vascular and the walls separating the blood spaces from the water are thin enough to allow respiratory changes to take place. Also in the periphery of the foot there is a great plexus of blood spaces just beneath the surface and it is probable that some respiration may occur here.

These animals can also carry on respiration for a considerable time in the absence of surrounding water. Along the banks of the Licking River I have collected animals which have been trapped in small pools after the water receded. Sometimes hundreds of them would be found in a small pool not over an inch deep and in which the water had been heated to a high degree by the sun. Others have been taken from the surface layer of dried mud, which according to government records of the Licking, had been out of the water for at least four weeks. If the apertures of the shells were turned down into the dried mud the animals would be found alive and would be active within a few minutes after being placed in water. However, if the apertures were turned up so the sun could strike the animal they were always dead. In these cases of trapped animals it is probable that their ability to survive is due to their ability to live on a small amount of oxygen rather than by obtaining their full supply by aerial respiration as in the case of some amphibious gastropods.

ALIMENTARY CANAL

The mouth, which is a narrow vertical slit, is situated at the anterior end of the snout and remains closed and inconspicuous unless the animal is feeding at which time it is spread open somewhat and the radula may be seen in motion.

The vestibule (Fig.), a short narrow passage, connects the mouth cavity with the cavity of the buccal mass usually known as the pharynx. Posteriorly the pharynx opens into the relatively small oesophagus, the change being rather abrupt. The oesophagus which appears flabby in contrast to the muscular buccal mass, continues straight posteriorly through the peri-visceral cavity, the cavity which surrounds the anterior part of the alimentary canal. Toward the posterior limit the oesophagus bears to the left to enter the visceral mass and empty into the stomach on the ventral side to the left of the midline.

There are two salivary glands which lie on either side of the anterior part of the oesophagus(Fig.). These glands are long, slightly convoluted tubes of a light yellow color. They become smaller at the extreme anterior end to form short ducts which pass through the nerve ring to enter the muscles of the buccal mass and open into the pharynx at this point.

The <u>stomach</u> is in contact with the liver and gonad posteriorly and anteriorly it is bounded by the style-sac and intestine. The oesophagus opens on the left side of the floor of the stomach into a deep groove. Immediately posterior to the oesophageal opening and also opening into the groove just mentioned is the single duct from the digestive gland. The roof of the stomach presents a corrugated appearance due to many parallel low folds alternating with shallow grooves.

From the floor of the stomach a number of ridges project into the cavity which are really folds of the stomach wall and are called gastric folds. The largest, which is the central fold, is pyriform in outline with the broadest end being posterior and gradually narrowing anteriorly to where it ends at the right anterior end of the stomach. This central fold may have smaller secondary folds and grooves on it which, however, are of slight importance. The width of the top of the central fold (Fig.) is slightly greater than the width of the base, so that its upper edges overhang to some extent. Lying next to the central fold is a much narrower outer fold, which originates at about the middle of the left margin and runs as a ridge around the inner fold along the left, posteriorly and partly on the right side. Due to the proximity of the outer and inner gastric folds, a narrow deep gutter is formed between the two which is continuous with the groove into which the oesophagus and digestive gland duct empty. On the left posterior margin of the stomach there originates a narrow lateral fold which runs directly cephalad to bend sharply on itself, the second limb being internal and parallel with the first, so that a groove is formed between the two. The second limb ends near the opening of the oesophagus and duct of the digestive gland, which are seen to lie near the beginning of the gutter between the outer and inner gastric folds. It would appear that the function of these folds is to direct the food contents of the stomach and to aid in their thorough mixing.

The right anterior portion of the stomach has developed a cuticular lining, the thickest portion of which lies opposite the opening of the style-sac, to be described below, and is termed the gastric shield.(Fig.)This is a slightly flexible, irridescent, irregular structure. Its shape is somewhat like a flat oblong plate which has been twisted in a spiral fashion to form an incomplete tube. The lower edge fits against the margin of the gentral gastric fold. The thick shield does not extend to the dorsal wall, but a thin cuticular continuation does extend half way across the anterior roof.

Directly in front of the stomach there is a chamber about three-fourths as long as the stomach, the style-sac (Fig.) It is oblong in outline and has very thick walls, darkly pigmented. The style-sac, as the name suggests, contains the crystalline style which projects through the circular opening into the stomach to fit against the gastric shield. The lining of the style-sac appears smooth on gross examination, and because of the pigment present, is irridescent.

Along the left side of the style-sac and opening by a slit with it into the stomach is a narrow groove which is really the beginning of the intestine.. This groove is anatomically in communication with the style-sac through all of its length, but functionally it is separated by two opposing ridges or typhlosoles which are approximately dorsal and ventral in relation to each other. There is not so much difference in size between the two typhlosoles although the dorsal is perhaps the larger and the ventral is the broader. The dorsal typhlosole is more or less pointed on its lower edge and this keel fits into a corresponding groove on the ventral typhlosole, so that the cavities of the groove, which is called the intestinal groove, and the style-sac are actually separate (Fig.).

The digestive gland occupies the apex of the visceral mass and is spirally coiled from the tip downwards. It is in contact with and completely covered by the gonad except for the very tip of the spire and a band along the columellar margin on each side of the genital duct (Fig.). The stomach, as already described, is embedded in the anterior end. The gland consists of a large number of tubules which vary in size and are bound together by connective tissue. The smaller tubules unite to form larger tubules which ultimately empty into the large duct which leads to the stomach and opens into the gastric cavity by a single opening (Fig.).

The intestine proper continues from the anterior end of the intestinal groove, curves dorsally over the anterior end of the groove, and passes in a loop over the style-sac back to the left side (Fig.). It then curves to the right and forward to pass into the rectum (Fig.). The rectum passes anteriorly in the mantle as a wide, flat, wrinkled tube to end in a small anus on the right side of the pallial cavity. The rectum is marked by many oblique transverse grooves, and it is in these grooves that the fecal matter is molded into fecal pellets.

The <u>radula</u> has a typical taenioglossid formula, 2-1-1-1-2, and contains about 50 transverse rows of teeth. It appears to be somewhat degenerate and apparently differs little from other pleurocerid radulae. For a description the reader is referred to the many taxonomic works on the Pleuroceridae.

HISTOLOGY OF THE ALIMENTARY CANAL

The "lips" and the margin of the mouth are covered by a low columnar epithelium similar to that covering the general body surface. Just inside the mouth the cells are very narrow and their height is at least twice that of the cells just outside the mouth. The nuclei are prominent and are located at various levels so as to produce a pseudostratified appearance. This area also has an unusually large number of gland cells which are of a mottled appearance and differ from the gland cells of the general body surface in that they are long and spindle-shaped and not flask-shaped as is typical. The epithelium lining the vestibule is peculiar in that it is covered by a very thick cuticular border and is entirely devoid of gland cells. The cavity of the pharynx is irregular in shape and varies in different levels. Likewise the character of the lining epithelium varies from tall columnar to low cuboidal in different regions.

The salivary glands, of which there is a single pair, are more or less round in cross section (Fig.) but they vary as to exact shape in different levels. Each is a long unbranched slightly convoluted, simple tube light in color. Often one gland is slightly longer than the other. The glandular part of the tube gives way anteriorly to a short narrower part which functions as a duct to empty the secretions into the cavity of the buccal mass. The cells making up the walls of the glandular part are tall, irregular, darkly staining cells, which bear a very few small scattered cilia. The bases of the cells rest on a delicate basement membrane. There is no histological difference between the glandular part and the duct.

The wall of the oesophagus is composed of the lining epithelium and a surrounding muscular layer. The latter is not divided into distinct longitudinal and circular layers but the fibers are arranged in an irregular fashion. It may be said that the muscular layers of the whole intestine are poorly developed. The cells lining the oesophagus are tall columnar cells of two kinds--glandular and ciliated cells of which the former greatly outnumber the latter. In fact, the oesophagus contains a larger proportion of glandular cells than any other part of the gut. The ciliated cells are very irregular in shape and the components of the cells are usually vague. In cross section, the lumen of the oesophagus is seen to be partially divided into three main parts by two pairs of longitudinal ridges (Fig.). Extending from the dorso-lateral region on each side, beneath each salivary gland, is a septum which extends ventrally about one-half way across the cavity. Extending dorsally from the floor, immediately on each side of the midline of the oesophagus, is a pair of low ridges with a narrow groove between them (Fig.). These septa become less prominent posteriorly, until immediately anterior to the stomach the oesophagus presents many low longitudinal striations which, however, disappear when the oesophagus is in a distended state.

The stomach is covered by a thin layer of connective tissue and muscle fibers, the latter having no regular arrangement into layers. The inner wall of the stomach is lined with ciliated epithelium similar to that found in other parts of the gut, except that it is not so tall and fewer gland cells are present. Opposite the opening of the style-sac the epithelium aquires a cuticular covering which forms the gastric shield (Fig.). The shape of the shield, as described above, is somewhat spiral. The left margin of the shield curves dorsally to terminate in a sharp edge which bears on an average of six pointed spines. These spines are continued on the outer wall of the shield as ridges which fade out ventrally. The posterior semi-liquid end of the style fits against the shield.

The cells underlying all the cuticular structures stain less ~~lighter~~ than the other gastric epithelial cells, and are much taller and narrower. The cells underlying the narrow band of cuticle along the roof are extremely tall. These cells, of course, bear no cilia, this being the only large expanse of the gut epithelium which does not. The epithelium covering the sides of the gutter formed by the outer and inner gastric folds is the most strongly ciliated of any found in the stomach, the cells covering the top of the inner fold having no cilia at all (Fig.)The cilia on the floor of the stomach are only weakly developed..

The dorsal inner surface of the stomach shows many low, parallel roughly transverse folds or ridges which in section are seen to be conical with rounded apices. The cells covering these ridges are ciliated but the cilia are poorly developed. The ridges are best developed dorsally and gradually become smaller laterally and ventrally.

The <u>digestive gland</u> lies directly posterior to the stomach and with the gonad makes up the remaining part of the visceral mass. It is composed of one undivided lobe of a yellowish brown color. It consists of a large number of tubules, the blind ends of which seldom reach the surface except on the columellar side because of the overlying gonad (Fig.). The tubules are bound together by connective tissue in which there are many blood spaces. The tubules, which are more or less circular in cross section, are lined by two kinds of cells, gland cells and ferment cells, the latter being the most numerous. One or more vacuoles are usually present in the ferment cells and they usually contain from one to six large bodies known as secretory bodies. These bodies are solid, rounded, and from dark brown to black in color. The gland cells are not so broad as the ferment cells and are more circular. The cytoplasm is finely granular but in general does not stain so deeply.

The products of the gland ultimately pass to the duct on the columellar side. The duct, which is single, becomes large at the anterior end, and opens into the floor of the stomach on the left side directly posterior to the opening of the oesophagus by a narrow slit (Fig.). This opening and the proximal part of the duct are lined with ciliated epithelium similar to that region of the stomach.

The style-sac is directly anterior to the stomach and in open communication with it, and also incompletely separated from the intestinal groove by a major and minor typhlosole as explained above. The style-sac and intestinal groove are surrounded by connective tissue. This connective tissue is pale, almost colorless and ~~structureless~~, and is interspersed with many lacunae with few nuclei.

The style-sac is lined by columnar cells which bear cilia which are strikingly developed and are all of exactly the same length. The proximal ends of the cilia appear to be fused so that in sections there is a narrow border adjacent to the inner ends of the cells. The cells stain rather lightly and are vacuolated. In the dorsal region these epithelial cells contain a large amount of pigment matter in the form of crowded black granules. The lower half of the cell contains the nucleus and is without pigment. No gland cells are present in the epithelium ~~style-sac~~. On the style-sac aspect of the major typhlosole there is a longitudinal ridge of very tall cells extending along almost the whole length of the style-sac. These cells are not vacuolated, contain no pigment and bear short cilia (Fig.). This ridge is only slightly above the surrounding level on the inner surface of the sac, and as the cilia are shorter than the cilia borne by the adjacent cells, the level formed by the distal ends of the cilia is inbroken. Toward the intestinal groove the cells become low columnar in character rather abruptly, and are weakly ciliated on the major typhlosole, and gradually take on the appearance of the characteristic intestinal lining, weakly ciliated with an abundance of gland cells.

The epithelium covering the minor typhlosole is made up of tall columnar cells with elongate nuclei, darkly staining cytoplasm and are strongly ciliated, no gland cells being present. The transition to intestinal epithelium is rather gradual. The intestinal groove is lined by typical gut epithelium of weakly ciliated columnar cells with an abundance of gland cells.

The crystalline style agrees in general with that described for other forms. It is about 1. 5 mm. long and 0. 7 mm thick, round with blunt ends, the end toward the stomach being in a semi-liquid condition and mixed with the stomach contents. In a normal animal it completely fills the style-sac. In optical section the whole structure is seen to have a spiral arrangement, the spiral being from left to right from the anterior to the posterior end. In a fresh style there is a distinct opaque core, the "food core" of some writers. The core is thickest at the posterior end and gradually narrows to a thin thread at the opposite end. The posterior semiliquid end projects into the stomach and fits against the gastric shield, practically filling the anterior part of the stomach.

The consistency and color of the style vary greatly. In a supposedly healthy normal animal it is a firm rod varying from a clear transparent to a smoky bluish color. There is some evidence that temperature or food supply and possibly oxygen supply may have some effect on the style. In animals kept for some time at a temperature of 3 degrees centigrade the style is a brownish color and the periphery is in a semi-liquid condition. I have never found a living animal with the style absent. On the other hand I have never found a style in a preserved specimen. However, if a fresh style is removed and placed in 95 per cent alcohol, it coagulates almost immediately, which suggests an albuminoid nature as has indeed been found to be the case by other workers on other animals. If a style is removed and placed in water it completely disappears in 20 minutes or less, the core being the first part to disappear. A crystalline style was not known to occur in any member of the family Pleuroceridae until recently when it was recorded as occuring in Pleurocera (Magruder, In press) caniculatum undulatum (Say) and Lithasia obovata (Rafinesque). It is probable that further investigation will disclose the presence of a style in other species of this family.

Beyond the intestinal groove, in the coils of the intestine, the lining epithelium is essentially the same as that in the intestinal groove. However, in this region a marked typhlosole is present (Fig.) covered by cells which are taller than those forming the remainder of the lining. This part of the intestine contains gland cells but they are not nearly so abundant as in the intestinal groove and oesophagus. The muscular layer is poorly developed.

The is a gradual transition from the comparatively small intestine to the wide transversely folded rectum (Fig.) which lies in the mantle. The muscular layer is practically absent in the walls of the rectum. The cells composing the lining epithelium are very regular low columnar cells with cilia well developed. Gland cells are present but not very abundant, the largest number being near the anus.

VASCULAR SYSTEM

The pericardial cavity is located on the left side of the body whorl at the extreme posterior end of the mantle cavity (Fig.). It is bounded posteriorly by the connective tissue surrounding the first part of the intestine and style-sac. The posterior renal chamber lies just dorsal and to the right and overlaps the pericardium slightly. The pericardium is somewhat square in outline and its posterior end extends for a short distance beneath the posterior renal chamber as a narrow tube-like extension. The pericardial wall is composed of one layer of low cuboidal cells resting on a thin structureless membrane through which the heart can be seen in the pericardial cavity.

The heart of Pleurocera caniculatum undulatum has one auricle and one ventricle (Fig.), the auricle being anterior to the ventricle. The auricle is a thin walled white sac approximately 0. 9 mm. in length, somewhat oval in outline with the broadest end anterior. The large efferent ctenidial sinus and the smaller efferent renal sinus open into the anterior end of the auricle, these being the only two vessels which bring blood directly to the heart. Posteriorly the auricle is separated from the ventricle by a marked constriction through which passes the short auricular-ventricular canal. I can find no valves in this region guarding the opening between the two chambers such as have been described for some other monotocardia.

Externally the auricle is covered by a thin almost structureless endothelium-like layer of protoplasm in which nuclei can be distinguished but no cell walls. I can find no lining of any sort inside the auricle or ventricle, the muscles appearing to project directly into the cavity. The auricular wall is comparatively thin and is composed of more or less loosely arranged, variously sized bands of muscles. The cavity of the auricle appears small because of the many bands of muscle fibers extending from its walls. As a result the auricular cavity appears sponge-like with many irregular deep pockets rather than as one clear-cut cavity.

Entering the auricle anteriorly with the efferent renal vessel is a nerve, a branch from the visceral ganglion. It enters the right auricular wall, passes posteriorly a short distance and divides into two branches of equal sizes which can be traced as far posteriorly as the anterior end of the auricular-ventricular canal.

The <u>ventricle</u> is pyriform in shape, about 1. 5 mm. in length, located immediately posterior to the auricle. It is yellowish in color and rather firm in a fresh animal. Originating from the posterior end of the ventricle is a short aortic trunk which immediately divides into the two main aortic trunks of the body, one going anteriorly and called the cephalic aorta, and the other, the visceral aorta, passing posteriorly.

The ventricular walls are thick and are composed almost entirely of muscle fibers. Like the auricle, the ventricle is covered by a thin endothelial layer but no inner lining is present, the muscles being exposed directly to the blood. The muscles are grouped into definite bundles of various sizes. The length of none of the bundles exceeds one-third the circumference of the ventricle. A great many of the bundles run more or less transversely and some obliquely but none runs longitudinally. The ends of the bundles are usually spread out in a finger-like fashion at each end where they are attached. These bands of muscle give the inside of the ventricle the appearance of having heavy ribs between which are sinus-like pockets.

External to this coarse muscular layer is another indistinct layer of branching muscles which run in all directions. The ventricular wall then is composed of an outer endothelial covering, an external thin muscular layer and an inner thick muscular layer. No ventricular valves were found.

Arising from the posterior end of the ventricle is the short aortic trunk which divided into the cephalic and visceral aortae, as mentioned above (Fig.). The cephalic aorta bends sharply to the left and passes anteriorly along the outer edge of the pericardial cavity. On the posterior side of this arch a large branch is given off which passes posteriorly, through the connective tissue surrounding the anterior end of the style-sac and intestine to the walls of the style-sac to end in several fine branches. The main trunk of the cephalic aorta leaves the pericardial aavity at the anterior end and passes beneath the efferent ctenidial sinus. It follows an oblique course toward the midline to enter the perivisceral cavity and passes dorsal to the oesophagus and salivary glands and just beneath the floor of the pallial cavity. In this region the vessel is enclosed in a mass of connective tissue which connects it to the parietal walls and to the adjacent organs. Just posterior to the cerebral ganglia, it turns ventrally and passes to the right of the base of the supra-intestinal nerve and then passes ventrally posterior to the right pleural ganglion. It then turns to the midline again where it gives off a branch to the buccal mass. This branch then redivides in the buccal mass into anterior and posterior branches. The anterior branch, supplies blood to the anterior part of the buccal mass, and sends branches to the snout and lips. The posterior branch, which is the larger, is distributed to the radula sac, the anterior part of the oesophagus and the salivary glands. The main trunk continues ventrally between the cerebro-pedal and pleuro-pedal connectives. Just anterior to the pedal commissure, over which it passes, the cephalic aorta divides into a right and a left branch each of which soon divides into an anterior and posterior branch of equal size (Fig.). The great expansion of the foot is no doubt aided by the large amount of blood supplied to it through the well developed arteries. Beneath the mantle margin the cephalic aorta gives off, usually to the left, one or two branches to the mantle and numerous smaller branches to the floor of the cavity and the oesophagus in this region, however, these smaller branches are extremely variable. A small artery is given off to each tentacle.

The large visceral artery leaves the short common aortic trunk and passes obliquely toward the right, just beneath the posterior edge of the posterior renal organ and directly anterior to the style-sac. It gives off a few small branches along its route in this region as it passes obliquely around the visceral mass, burried in connective tissue, to the columellar side. When it reaches the genital duct it turns posteriorly and proceeds posteriorly accompanied by the genital duct and the visceral nerve. The visceral artery, after giving off branches to the posterior part of the stomach and anterior part of the digestive gland and gonad, ends in many small branches in the apex of the visceral mass.

The blood which is distributed by the arteries is passed into many small excavations in the tissue. The venous system is composed largely of these spaces or sinuses which usually lack definite walls and consequently are hard to define since they have no definite pattern.

The foot is one of the most vascular organs in the body. The blood from the large pedal arteries finally enters the plexus of sinuses in the periphery of the foot, and these are so numerous as to give the foot a spongy appearance in sections. The blood is returned by way of the pedal sinus to the center of the foot, then dorsally into the perivisceral sinus into which it empties. The blood is probably aided in its circulation in the foot by movements of the pedal muscles. The foot almost always shows some motion even when the animal is at rest.

The perivisceral sinus lies below the floor of the pallial cavity and above the foot, surrounding the anterior part of the gut. The blood enters this sinus from the foot, head and surrounding parts. From here the blood goes to the anterior renal chamber and through the mantle directly to the afferent ctenidial sinus, or through the mantle to the afferent ctenidial sinus directly.

The periintestinal sinus lies for the most part on the columellar side of the animal and collects blood from the stomach, style-sac, digestive gland and genital system. Part of this blood returns by way of the anterior renal chamber to the afferent ctenidial sinus, and part by way of the posterior renal chamber to the efferent renal sinus directly to the heart.

The branchial sinus is a collection of sinuses in the mantle region which eventually form the definite afferent ctenidial sinus lying along the right side of the ctenidium. Surrounding the rectum is the large rectal sinus which collects blood from part of the mantle, genital folds and surrounding region. Part of this blood may pass directly to the afferent ctenidial sinus and part, by way of the anterior renal chamber to the afferent ctenidial sinus. The afferent ctenidial sinus sends a small branch into each ctenidial leaflet where the blood is aerated in the thin walled platelets. The blood is collected from the ctenidium by the efferent ctenidial sinus which lies along the left margin of the ctenidium and just to the right of the osphradium from which it also collects blood. This sinus passes directly posteriorly to enter the auricle.

In the dorsal part of the posterior renal organ there is a small sinus, the afferent renal sinus, which collects blood from the rectal region and terminal part of the intestine. This sinus breaks up into a number of small branches thus forming a renal portal system. The blood from this plexus is collected in the efferent renal sinus which opens into the auricle. The blood passing through this system is, of course, not aerated in the ctenidium so that the blood in the heart is mixed.

Summary of Blood Circulation. The blood passes from the ventricle to part of the style-sac, the head, part of the mantle, oesophagus, buccal mass, foot and associated organs by way of the cephalic aorta. Blood passes to the digestive gland, stomach, gonad, part of the style-sac and related organs through the visceral aorta and its branches. Blood from the various parts of the body is finally collected into two main sinuses--the perivisceral and the periintestinal sinuses, from which it goes to the heart by one of three general routes: (1) directly to the afferent ctenidial sinus by way of the perirectal sinus and mantle sinus, and through the gills to the efferent ctenidial sinus, thence to the auricle; (2) through the anterior renal chamber and to the afferent ctenidial sinus to follow the same route; (3) to the posterior renal chamber by way of the afferent renal sinus, through the renal plexus to the efferent renal sinus into the auricle without aeration.

NERVOUS SYSTEM

The nervous system has never been described for any member of this family so unfortunately no comparisons can be made. In general, the nervous system of this species is similar to that described for other streptoneurous gastropods. In the following account I have not gone into detail concerning the terminology of the different ganglia and nerves. This has been been adequately discussed by Spengel ('81) and by Bouvier ('87) in his memorable work on the nervous system of the prosobranchs. The names which I have used are the generally accepted names of Spengel, such as cerebral, buccal, pedal, pleural, supra- and subintestinal and visceral. The nervous connections between like ganglia of opposite sides are called commissures and the connections between unlike ganglia of the same or opposite sides are called connectives.

In gross dissections the smaller nerves, which are white were very hard to follow as most of them are either in or against a background of white muscular tissue. A method was devised whereby the nerves could be stained by an aqueous solution of methyl green causing the nerves to stand out prominently so that they could be traced with little difficulty.

In the drawing of the nervous system, (Fig.) only the main nerve trunks are shown. It is not practical to show the many small branches which vary a great deal as to size, number and relative position and can ~~could~~ not be shown in proportion in a drawing of this size.

The paired cerebral ganglia are connected with each other toward their posterior ends by a short thick cerebral commissure (Fig.) which passes dorsal to the oesophagus. Each ganglion is roughly pear-shaped with the lateral side being the longest. The anterior end of each ganglion is pointed where it gives off several large nerves to the anterior head region. The posterior end lies directly dorsal to the anterior end of the pleural ganglia.

The cerebral commissure is short, thick and rather wide, the narrowest part being in the center. It varies in length, being so short in some animals as to give the appearance of the cerebral ganglia being fused. No indication is seen of a labial commissure running ventral to the oesophagus as is found in some prosobranchs.

Each cerebral ganglion is connected to the buccal ganglion of the corresponding side by a cerebro-buccal connective. This originates on the anterior ventral sideof the cerebral ganglion and passes anteriorly to connect with the buccal ganglion at the lateral posterior end. These connectives are extremely small and as they run much of the way in light colored muscles of the buccal mass they are very hard to follow unles stained.

Each cerebral ganglion is connected to the pedal ganglion of that side by a long round cerebro-pedal connective which arises on the ventral side of the cerebral ganglion and passes ~~directly~~ ventrally to the dorsal side of the pedal ganglion. These cerebro-pedal connectives often show a variable number of enlargments along their course which appear superficially to be ganglia, but a study of their internal structure shows them not to be such. Each cerebral ganglion is connected with the pleural ganglion of the same side by a short connective.

The nerves arising from the cerebral ganglia are identical on the two sides, therefore the branches of only one side will be described.

Anterior Nerves.

1. A medium sized labial nerve (Fig.) arises from the dorsal anterior side of the cerebral ganglion and courses laterad to the dorsa-lateral side of the perivisceral cavity, where it follows along the ceiling of the cavity, being attached to the wall by connective tissue as well as by small nerves which branch to the muscles of the snout. This nerve terminates at the anterior end in the muscles at each side of the mouth opening.

2. A large labial nerve (Fig.) arises on the anterior dorsal surface near the most anterior part of the cerebral ganglion. Its point of origin is slightly lateral and anterior to that of the first labial nerve. It passes obliquely forward along the wall of the cavity ventral to the nerve just described, around the buccal mass giving off many smaller branches to the snout muscles to be finally distributed in the region of the lips.

3. The third labial nerve (Fig.) arises directly lateral to the second labial nerve, and is about the same size. In some cases the origins of the second and third labial nerves are fused so that they appear as branches of a single nerve. This nerve passes anteriorly parallel with the other

labial nerves until about the middle of the snout, where it passes ventrally beneath the buccal mass and finally terminates in the ventral lip region.

4. ~~This nerve, which is~~ the pharyngeal nerve, (Fig.) originates at the ventral anterior end of the cerebral ganglion and passes forward along the floor of the perivisceral cavity It curves sharply mediad at the level of the anterior end of the buccal mass to enter this organ where it is distributed to the anterior muscles of the buccal mass.

5. The fourth labial nerve (Fig.) is the only remaining anterior nerve of the cerebral ganglion. It originates just ventral to the pharyngeal nerve and passes anteriorly, parallel with it. Its anterior end terminates in two branches of the same size, one going to the lip region and the other to the muscles on the ventral side of the buccal mass.

Lateral Nerves.

1. The large tentacular nerve (Fig.) arises on the dorsal side of the cerebral ganglion on the anterior lateral surface. This is the largest nerve originating from the cerebral ganglion. It passes laterally to where it enters the muscles, and passes obliquely forward to the base of the tentacle where it enters the tentacular tissue, giving off many small branches along its route to the end of the tentacle. The tentacular nerve somtimes passes through the large retractor muscle of the buccal mass. No sign of a tentacular ganglion was found.

2. The optic nerve (Fig.) is second in size only to the tentacular nerve. The optic nerve arises from the ventrolateral side of the cerebral ganglion and passes laterally to

enter the muscles of the wall of the perivisceral cavity and pass directly to the eye located at the outer base of the tentacle. The optic nerve usually, but not always, gives rise on its posterior side to a small nerve to the muscles in the region immediately posterior to the eye (Fig.).

3. The statocyst nerve originates from the ventral side of the cerebral ganglion at its posterior end. It passes directly ventrally, just anterior to the cerebro-pedal connective, passing to the outside obliquely across the pleuro-pedal connective to terminate in the walls of the statocyst, which are located at the posterior dorsal ends of the pedal ganglia. This nerve is extremely small.

The buccal ganglia are paired and lie just ventro-lateral to the anterior end of the oesophagus, anterior to and slightly above the level of the tip of the radula sac. Each buccal ganglion is round and small. They are connected by a long thick commissure whose diameter is approximately half that of the ganglia. The buccal ganglia and connectives are entirely covered by the tissue of the buccal mass and cannot be seen until dissected out of this region. A very small nerve originates from each ganglion and passes anteriorly to end in several twigs which supply that part of the buccal mass. However, one branch goes to the rest of the buccal mass to supply the remaining muscles.

The pedal ganglia are paired and similar. They are oval in shape and connected by a single short commissure. Dorsally the pedal ganglia are connected to the cerebral ganglia by the long cerebro-pedal connectives and to the pleural ganglia by the pleuro-pedal connectives.

From each pedal ganglion there arise two large nerves, an anterior and a posterior one. Besides these there are usually several small and irregularly arranged nerves which are not constant in their appearance. The anterior nerve passes forward through the pedal muscles and gives off many branches which rebranch in their turn. There is no regularity in the number or pattern in these branches from the anterior pedal nerve.

The posterior pedal nerve is about the same size as the anterior pedal nerve and passes posteriorly beneath the opercular region of the foot. From it originate many branches, which, as in the case of the anterior nerve, follow no definite pattern. The number of nerves originating from the anterior and posterior pedal nerves is large, making the foot one of the best supplied organs in the body so far as nerves are concerned. The sole of the foot is extremely well supplied with nervous elements.

Several small nerves, arising from the posterior pedal nerve are seen to pass in the direction of the columellar muscle, however, I was never able to trace these branches actually to the muscle and I am inclined to believe they end in the dorsal foot muscles.

The pedal ganglia are more or less surrounded by a mesh-work of connective tissue strands between which are many large spaces composing part of the pedal sinus. The main cavity of the pedal sinus lies between the ganglia.

The pleural ganglia are paired but not similar in shape (Fig.) nor are the nerves which arise from them symmetrically arranged, therefore, these ganglia will be described separately.

The left pleural ganglion (Fig.)lies close to the left cerebral ganglion and is connected with it by the short cerebro-pleural connective. The shape of this ganglion is oblong and superficially it appears to be two ganglia. However, the whole mass is one ganglion separated by a constriction into a larger anterior and a smaller posterior lobe. Posteriorly this ganglion is closely associated with the subintestinal ganglion, being separated from it by a constriction.

The anterior lobe of the left pleural ganglion gives rise to two nerves, the most anterior and smallest of which is a small lateral nerve (Fig.) which originates from the dorsal side of the ganglion and passes dorso-laterally to enter the muscular wall of the perivisceral cavity to supply the muscles in the neck region.

The second nerve to arise from the anterior lobe of the left pleural ganglion is the left pallial nerve (Fig.). This nerve originates on the dorso-lateral side of the anterior part of the left pleural ganglion and passes posteriorly on the left side of the oesophagus beneath the left salivary gland. It then curves to the left and passes for some distance through the muscles to the junction of the mantle and body. At this point it gives off a small branch posteriorly which ramifies in the muscle. This small branch meete and fuses with another branch of similar size from the supraintestinal ganglion. The main branch of the left pallial nerve enters the mantle and passes toward the right side in the anterior part of the mantle tissue. The course of this nerve through the mantle is very tortuous, giving off many branches, many of which extend anteriorly to the mantle margin.

The only nerve to originate from the posterior lobe of this ganglion is the columellar nerve (Fig.). This medium sized nerve leaves the ganglion from the center of the lateral side of the posterior lobe. It passes posteriorly along the floor of the perivisceral cavity parallel with the subintestinal nerve to be described below. At about the region of the mantle margin, it enters the floor of the perivisceral cavity to pass to the columellar muscle. A short distance anterior to this point, it gives rise on its right side to a small nerve which passes beneath the subintestinal nerve, curves posteriorly and disappears into the muscles of the floor of the cavity.

The right pleural ganglion is broader than the left and is not divided into two parts as is the left (Fig.). Its anterior end projects slightly beneath the right cerebral ganglion and is connected to it by the short vertical cerebro-pleural connective. Three nerves arise from the right pleural ganglion. The most anterior of these (Fig.) arises from the dorso-medial side and passes directly laterally to terminate in the muscles of the neck. Posteriorly the right pleural ganglion narrows to a point where two large nerves are given off side by side. The most median of these is the large supraintestinal nerve (Fig.). This nerve passes obliquely posteriorly toward the left side dorsal to the oesophagus and salivary glands and ventral to the cephalic aorta. It passes to the left wall of the perivisceral cavity where a medium sized round ganglion is formed lying in the muscular tissue. From this ganglion, which is the supraintestinal ganglion (Fig.), are given off several smaller nerves the total of which varies in different animals. One of the branches which appears constantly passes laterally to the junction of the mantle and body, where a small secondary branch is given off which passes anteriorly to anastomose with branches from the left pallial nerve. This anastomosis between these nerves composes what is known as zygoneury. One or more large branches pass through the mantle to the osphradium where they form the large nerve which runs the length of the osphradium and forms the core of this organ. Other nerves belonging to this complex pass to the mantle, mantle margin and to the anterior end of the ctenidium, while other small branches pass to the parietal wall. The chief nerve arising from the supraintestinal ganglion continues posteriorly to the left of the oesophagus, this being the left visceral connective.

Originating from the right pleural ganglion immediatley lateral and ventral to the supraintestinal nerve is another large nerve, the right pallial nerve (Fig.). This nerve passes posteriorly along the right side of the perivisceral cavity and to the right of the oesophagus. A short distance posterior to its origin, it gives off a small lateral branch which passes posteriorly parallel with the main nerve for a short distance, then it passes ventrally into the muscles of the neck region. At the level of the posterior end of the subintestinal ganglion there is a thick nervous connection (Fig.) between that ganglion and the nerve being described. At the region of the mantle margin the nerve curves to the right and enters the wall of the perivisceral cavity. Just ventral to the right mantle margin a small posterior branch is given off to the anterior part of the genital folds and muscles of this region. Soon two large genital nerves are given off (Fig.) which pass to the anterior and middle parts of the genital folds where they pass along the base of the folds. The larger branch passes to the external fold. In the gutter formed by the junction of the mantle and body wall the right pallial nerve curves dorso-laterally into the right anterior part of the mantle.

The subintestinal ganglion is separated anteriorly from the left pleural ganglion by a constriction (Fig.). On the right posterior end originates the thick connection with the right pallial nerve. Directly posterior the ganglion gradually narrows to form the subintestinal nerve, the only nerve to originate from this ganglion excepting the connection mentioned above. At the base of the subintestinal nerve there arises, on the right side, a small nerve which passes posteriorly to enter the muscles in this region. A short distance posterior to this nerve another small nerve is given off which is distributed to the same region. The main nerve passes posteriorly as the right visceral connective to the visceral ganglion. At the level of the posterior end of the genital folds it gives rise to two or three medium sized genital nerves on the right side which pass directly laterally to terminate in the posterior ends of the genital folds.

The two visceral connectives pass posteriorly and unite to form the visceral ganglion (Fig.). This is an indistinct "Y-shaped" ganglion which lies dorsal to the columellar muscle, ventral to the renal organ and the anterior end of the stomach. Only one main nerve originates from the posterior end of the visceral ganglion and irregular branches from this innervate the various organs in this region. The main trunk passes posteriorly to the digestive gland, gonad and posterior end of the stomach, parallel with and very near the genital duct and the visceral aorta.

SENSE ORGANS

The statocyst was called the otocyst by earlier workers and the nerve supplying it the auditory nerve. However, Tschachotin ('08), who has investigated this organ in some of the mollusca, has come to the conclusion that the organ is one of equilibrium rather than hearing and that it serves to regulate the animals position in space. In Pleurocera caniculatum undulatum the statocysts, as in other gastropods, are paired. They are located at the posterior dorsal end of each pedal ganglion and connected to that ganglion by connective tissue which forms a thin envelope around the organ. The cavity is lined by a single layer of low cuboidal epithelium in which the cell walls are very indistinct.

Some of the cells bear small, weakly developed, cilia-like processes on their inner ends. These "cilia" are very sparse and have no definite pattern, many of the cells appearing to have none at all. The cells which do not bear any of these cilia appear identical in all other respects.

The cavity of the statocyst is almost filled with small colorless statocontia which are transparent. The number of statocontia in each statocyst varies in different animals and even in the two sides of the same animal. There are usually from 30 to 40 statocontia in each statocyst. Sometimes there are two or three statocontia which are larger than the others, the larger ones being in the center with the others arranged around it. The average shape may be described as "barrel-shaped" (Fig.)and in the case of the larger ones there are faint longitudinal striations which increase the resemblance to a barrel. A few of the statocontia may be cigar-shaped and a few small ones round. When dilute HCl is applied, they dissolve with effervescence almost immediately.

The eyes are located at the outer bases of the tentacles, appearing superficially as small black spots. Microscopically the eye is seen to be almost round with the diameter from the optic nerve to the outer epithelium being slightly greater.

The body epithelium is continued over the eye to form the outer cornea, the cells making up this layer being just as tall and in some cases taller than in other parts of the surface epithelium. However, these cells lack the pigment found in the cells of the general body epithelium. Surrounding the eye and outer end of the optic nerve, and continued for some distance along the optice nerve is a layer of connective tissue. This connective tissue layer is continued as a thin layer beneath the outer cornea, appearing as a layer of closely packed irregularly shaped cells with rounded nuclei.

The retina is cresent-shaped with the deepest part located in the center opposite the optic nerve. The retina is composed, as far as I can ascertain, of one type of cell. These retinal cells are very tall cells which bear a brush of "hairs" or cilia-like processes on their outer ends (Fig.). The outer two-thirds of the cell is black because of the presence of a large number of large, round, black pigment granules. The base of the cell is drawn out into a narrow pointed end which appears, structurally at least, to be continuous with the nerve fibers from the optic nerve. Toward the extreme outside of the retina are a few cells which do not bear the cilia-like processes. These may correspond to the supporting cells described for some gastropods (Prashad '25). The edges of the retina are continued as a thin and almost structureless inner cornea, the cells of which do not have definite outlines and are devoid of pigment.

The cavity surrounded by the inner cornea and retina is filled by a well developed round pale yellowish lens. In sections it appears as a pale structureless round mass which does not take any of the common stains.

RENAL ORGAN

The renal organ is located to the right and adjacent to the pericardium. It is divided into a larger posterior part which lies nearest to the pericardium and a smaller anterior part which is located on the right side of the whorl (Fig.). The posterior renal organ can be seen , after removal of the shell as a light yellow organ, oblong in shape with faint lines or striations on its surface. When seen in section it appears as a spongy, very vascular gland made up of cells arranged in a crowded fashion. The organ is composed of many lamellae which apparently have fused together. This part of the renal organ is supplied almost entirely with venous blood by way of the afferent renal sinus and is drained by the efferent renal sinus directly into the auricle. The posterior renal organ is connected with the pericardial cavity by a very small opening on the one hand and with the chamber of the anterior renal organ on the other.

The anterior renal organ lies on the right side of the body and is much smaller than the posterior part. Its surface presents a very definite coarse striated appearance due to the internal lamellar stucture. When open this part of the renal organ is seen to have a spacious cavity into which hang a number of thin triangular lamellae. In sections these lamellae are seen to be covered with a regular cuboidal epithelium. In the center of each is a large blood space separated from the epithelium by a very thin basement membrane. The cavity of the organ opens into the tip of the pallial cavity to the right of the ctenidium by a small oval slit with thick ciliated "lips". The blood supply has been described in the section ofi the blood system. From a survey of the literature it seems that there is a lack of definite information concerning the prosobranchiate renal organ especially as to its function, and it would appear particuliar desirable to reinvestigate the functions as well as make a comparative histological study on some of the representative groups of fresh water prosobranchs.

REPRODUCTIVE SYSTEM

The present study seems to demonstrate without much doubt that the sexes in Pleurocera caniculatum undulatum are separate. Over 720 specimens have been examined and in no case was any evidence of hermaproditism found. As is the case in many and perhaps all of the members of this family there are no external genital organs present in this sp~~ecies~~. The only external character present was described by Stimson ('64) and is best summed up by Baker ('28): "The only apparent difference between the sexes appears to be the presence of a pit of sinus in the neck between the tentacle and operculigerous lobe, which is present in the female (with ova) and absent in the male (with sperm)..... A canal descends toward the base of the foot from this opening and becomes lost in the muscular tissue". This character was present in the females studied and was indicative of the sex in every case. No other external sexual character was discovered.

The position of the gonad is quite different from that of Pleurocera acuta Rafinesque briefly described and figured by Baker ('28). The gonad of Pleurocera caniculatum undulatum is large and lies on the surface of the digestive gland, and reaching to and forming the tip of the visceral mass (Fig.). The testis, which is usually larger than the ovary, surrounds the digestive gland except for a strip on each side of the genital duct. The testis has a lobulated appearance on the surface and is always a bright yellow color. It is composed of nu merous branched tubular follicles. The sperm duct originates near the apex of the visceral mass and passes anteriorly with the visceral artery and nerve. At the region of the posterior end of the mantle cavity the closed genital duct ends and the genital tract continues anteriorly as two opposed laminae with the ventral edges joined to the floor of the pallial cavity on the right side at the angle formed by the floor and the mantle. Posteriorly these folds are taller and are swollen and convoluted in an adult animal. The right fold is the taller and fits against and over the left to form an incomplete tube through which the genital products supposedly pass (Fig.).

The genital folds are lined by ciliated columnar cells between which are a large number of gland cells. Covering the outside of the folds are low columnar cells and an even greater number of gland cells than on the inside. Just beneath the surface epithelium is a thin layer of connective tissue and muscle tissue, and in the center of each fold is a large blood sinus which is in connection with the perirectal sinus. Passing across the lumen of the sinus are a number of fine strands of muscle tissue.

The spermatozoa are of two kinds: (1) the hair-shaped sperm called the eupyrene (Meeves '03) and (2) the worm-shaped or oligopyrene sperm neither of which, in this form, shows any movement (Fig.). It is probable that here as in other similar cases, only the former type is capable of fertilizing the egg. Although these two types of spermatozoa have interested zoologists since their discovery, little or nothing is known as to the function of the oligopyrene type (Siebold '36, Leydig '50, Baudelot '63, Simroth '91, '07, Reinike '12).

The eupyrene spermatozoa (Fig.) consists of an elongate deeply staining head behind which is a long flagellum that gradually becomes smaller from the head to the tip. In front of the head there is a hook-shaped structure which is as long as the head. It is to be noted that this sperm is ~~xx~~ very similar that of Goniobasis livescens correcta (Brot.) described by Jewell ('31). The terminal hook is either removed or invisible ~~or removed~~ in most stained preparations, but it can readily be seen in fresh preparations.

The oligopyrene spermatozoa (Fig.) are more abundant in the spring than in any other season of the year. They are larger than the eupyrene and do not resemble them in the least. They are wider in the middle and taper gradually toward the ends which are blunt and rounded. No nucleus is visible but the whole is filled with coarse granules except for a narrow streak in the center reaching the whole length, and a small clear area at one end. Arising from the end where the clear area is located, is a tuft of five to seven large flagella. Jewell ('31) does not mention this type of sperm as occuring in Goniobasis livescens correcta (Brot.).

The female reproductive system is very similar to ~~exactly like~~ that of the male except that the gonad is, in general, smaller and of ~~is~~ a reddish pink color rather than yellow. The ovary consists of branched tubular follicles. The epithelium covering the ovary is continuous with that covering the rest of the body and is composed of very low cuboidal cells with round nuclei. Under the epithelium is a thin layer of connective tissue containing blood spaces and blood vessels. Ova in various stages of growth can be seen attached to the germinal epithelium. The position and structure of the genital folds and duct is exactly the same as in the male.

Neither copulation nor egg laying has ever been observed in this species, nor have egg masses bee seen. In fact, the eggs of only five species in the entire family have been recorded (Jewell '31, Van Cleave '33, Winsor '33). There is very definite need for further observation not only for a study of the minute anatomy of the gonads of members of this family but also on breeding activity and embryology.

SUMMARY

Approximately 720 gastropods, Pleurocera caniculatum undulatum (Say), belonging to the family Pleuroceridae, order Ctenobranchiata, were dissected and the details of the anatomy investigated. The general anatomy was found

to be very similar to that of other members of this order. Of particular interest, however, is the discovery of a crystalline style and associated structures which have not before been described in this family. Likewise, two types of spermatozoa have been identified, the eupyrene and the oligopyrene types. This is the first record of spermatozoan dimorphism in the family Pleuroceridae. This study is intended as a basis for the investigation of the anatomy of other members of this family.

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(I have seen only an abstract of this paper.)