

# A New Species of the Genus *Paromalostomum* (Turbellaria: Macrostomida) from New England<sup>1</sup>

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*Abstract.* *Paromalostomum coronum* n. sp. from a high-energy beach at Reid State Park, Georgetown, Maine and from Manomet, Massachusetts is described. Distinguishing features are the accentuated coronal shape of the cuticular apparatus of the bursa, a distinctive penis-glandular stylet complex with an approximate 1:1 size ratio between the distal portion of the penis stylet and the glandular stylet and a penis stylet which has an end-hook and two asymmetric thickenings at both ends of its distal portion. *P. coronum*, always abundant during this study, is a voracious predator feeding on a variety of prey. Eggs are deposited throughout the year and the juveniles emerge after 12–35 days.

Examination of the interstitial fauna living in coarse sand at Griffith's Head Beach, Reid State Park, Georgetown, Maine revealed the great faunal diversity, including an abundant macrostomid turbellarian of the genus *Paromalostomum* which could, in fact, be considered the dominant form. This turbellarian does not correspond to any described species of the genus. None of the eight presently described species have been reported from North America. Seven have been reported from Europe and the eighth from Santa Cruz in the Galapagos Islands in the Pacific. However, Rieger (1977) illustrates the male copulatory apparatus of 14 undescribed species of *Paromalostomum* from the North American Atlantic Coast. *Paromalostomum coronum* n. sp., in addition to being abundant in beaches where it occurs, is a voracious predator. The trivial name *coronum* is derived from the unique crown-like shape of the midpiece of the cuticular apparatus of the bursa.

## MATERIALS AND METHODS

Samples of coarse sand were collected from August 1975 to March 1977 from various depths in the intertidal zone at Griffith's Head Beach, Reid State Park, Georgetown, Maine, and at Manomet Beach, Manomet, Massachusetts in early 1977.

Animals were extracted from the substrate by relaxing them for 5–15 min in 7% MgCl<sub>2</sub> and washing through a 75- $\mu$ m-mesh screen. Subsequently, they were washed off of the screen into fingerbowls containing fresh sea-water. The macrostomids were maintained in fingerbowls on a running sea-water table where they were fed *Artemia* nauplii and interstitial copepods. Adults were maintained in this way in good condition for up to two months.

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Animals used in whole-mount preparations were relaxed in 7% MgCl<sub>2</sub>, fixed in Hollande's fluid, dehydrated in a graded alcohol series, and mounted unstained in glycerin. Squash preparations, prepared by extreme compression under a coverslip, were mounted directly in polyvinyl-lactophenol with acid fuchsin.

Relaxed specimens were prepared for general histological observation by fixation in Zenker's stock, Hollande's fluid, Rossman's fluid, or Gendre's fluid. The specimens were dehydrated in a graded alcohol series to 95% ethyl alcohol and embedded in polyester wax (Steedman, 1960). Before embedding, the worms were stained temporarily with acid fuchsin in 95% alcohol for greater ease in orienting and sectioning. Transverse, frontal, and sagittal sections of a total of 102 specimens were cut at 4, 5, 6, 7, 8, or 10  $\mu$ m on a rotary microtome, affixed serially to slides with albumen and 10% formalin or distilled water and stained with either Heidenhain's "azan" or Heidenhain's iron hematoxylin counterstained with eosin Y or fast green.

Measurements were made on living and fixed material and are the averages of 12–18 specimens in various states of contraction. Due to variable contraction in both living and fixed specimens, measurements often are given in terms of percent of total body length. Measurements of convoluted structures were made by the summation of a series of measurements taken along their tangential axes. The terminology used in the description follows that of Rieger (1971a,b).

#### SYSTEMATIC ACCOUNT

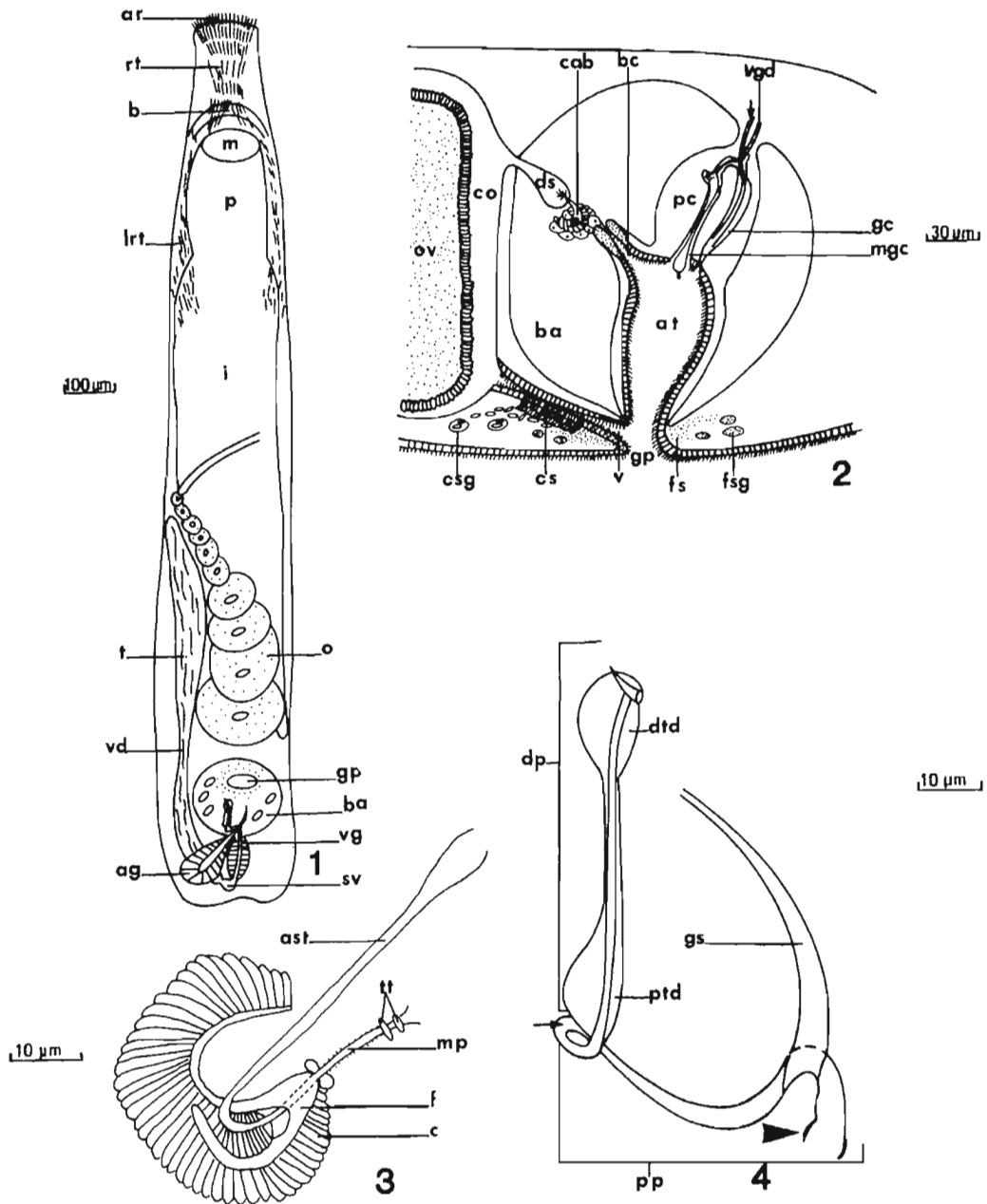
- Dolichomacrostomidae Rieger, 1971  
 Dolichomacrostominae Rieger, 1971  
*Paromalostomum* Meixner in Ax, 1951  
*Paromalostomum coronum* n. sp.  
 (Figs. 1–11)

#### *Description*

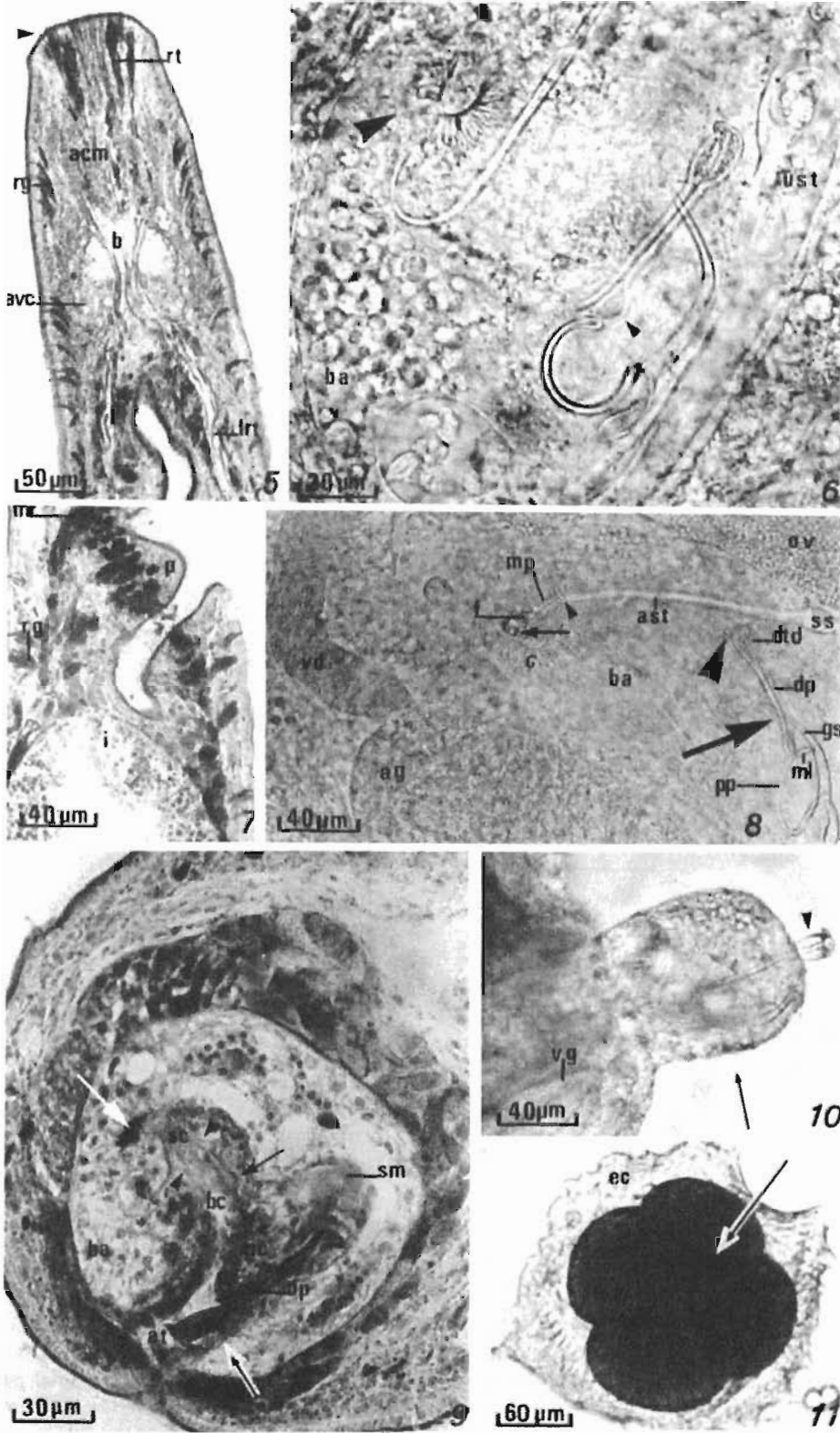
White, with intestine taking on color of food content. Adults up to 3.5 mm long; juveniles as small as 0.35 mm. Surface totally ciliated. Adhesive papillae small. Rhabdites missing on anterior 6% of total body length. Rhammite tracts arise from glands in pharyngeal area, pass anteriorly to apex through cerebral ganglion. Testis, single, fusiform, averaging 0.37 mm in length, located somewhat posterior to mid-body on right side, 45% of total body length from mouth,

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FIGS. 1–4. *Paromalostomum coronum* n. sp. Fig. 1. Entire animal, drawn from living specimens; ventral view. Fig. 2. Schematic representation of the bursal region reconstructed from serial sections; arrow indicates the duct leading from the accessory gland to the glandular stylet. Fig. 3. Cuticular apparatus of the bursa drawn from living specimens and squash preparations. Fig. 4. Penis and glandular stylets drawn from living specimens and squash preparations; arrow indicates the slight thickenings at the extreme proximal end of the penis stylet. Abbreviations: ag, accessory gland; ar, anterior rhammites; ast, attached sperm tube; at, genital atrium; b, cerebral ganglion;



ba, bursa; bc, bursal canal; c, corona of the midpiece of the cuticular apparatus of the bursa; cab, cuticular apparatus of the bursa; co, caudal section of the oviduct; cs, coarse secretion lining the vagina; csg, coarse secretion gland cells; dp, distal portion of the penis stylet; ds, ductus spermaticus; dtd, distal thickening of the dp; f, funnel-shaped section of the midpiece of the cab; fs, fine secretion lining the vagina and at; fsg, fine secretion gland cells; gs, glandular canal; gp, gonopore; gs, glandular canal; gp, gonopore; gc, male genital canal; mp, mouthpiece of the cab; o, ovary; ov, ovum; p, pharynx; pc, penis complex; pp, proximal portion of the penis stylet; ptd, proximal thickening of the distal portion of the penis stylet; rt, rhammite tracts; sv, seminal vesicle; t, testis; tt, terminal thickenings of the mouthpiece of the cab; v, vagina; vd, vas deferens; vg, vesicula granulorum; vgd, duct leading from the vg to the penis stylet.



ventral to intestine, toward right of body, next to ovary. Vas deferens 19% of total body length. Seminal vesicle  $24 \times 24 \mu\text{m}$ . Vesicula granulorum surrounded by thick muscular layer, averaging  $88 \times 46 \mu\text{m}$ . Relatively long duct,  $39 \mu\text{m}$ , connecting vesicula granulorum to penis stylet. Penis stylet, averaging  $178 \mu\text{m}$  in length, with two sections: (1) rigid, distal, averaging  $68 \mu\text{m}$  in length, and (2) flexible, twisted proximally, averaging  $110 \mu\text{m}$  in length. Distal with indistinct end-hook, two asymmetric thickenings at either end; one next to distal end-hook, the other next to well-formed mid-loop of penis stylet. Accessory gland flask-shaped, averaging  $138 \times 112 \mu\text{m}$ . Glandular stylet, averaging  $50 \mu\text{m}$  in length, moderately bent, tapers gradually toward distal end; proximal end in intimate contact with that of penis stylet. Ovary, sac-shaped, averaging  $0.578 \text{ mm}$  in length, located ventrally toward left of body. Its posterior end, 71% of total body length caudad from mouth. Cuticular apparatus of bursa in three parts: (1) midpiece, C-shaped with two sections; funnel-shaped section,  $10 \times 7 \mu\text{m}$ , fits into concavity in second section, the corona  $27 \times 10 \mu\text{m}$ , curved rod with digitiform projections; (2) mouthpiece,  $35 \mu\text{m}$  in length, leads from midpiece into ductus spermaticus; (3) attached sperm tubes, averaging  $141 \mu\text{m}$  in length. Unattached sperm tubes may occur. Gonopore, ventral, subterminal, 14% of total body length rostrad from posterior end.

*Type locality.* Griffith's Head Beach, Reid State Park, Georgetown, Maine, U.S.A.

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FIGS. 5-11. *Paromalostomum coronum* n. sp. Fig. 5. Anterior end; small arrow head indicates an anterior rhammite. Note the insunk epithelium just anterior to the rhabdite glands. Fig. 6. Living specimen, bursal region. Heavy arrow head indicates the proximal thickening of the distal portion of the penis stylet. Fig. 7. Pharyngeal-intestinal junction region, showing the mouth opening. Note the dense concentration of mouth rhammites. Fig. 8. Living specimen, bursal region. Heavy arrow indicates the indistinct end-hook of the penis stylet; thin arrow indicates the cuticular apparatus of the bursa; small arrow head indicates the terminal thickenings of the mouthpiece of the cuticular apparatus of the bursa. Fig. 9. Bursal region. Small arrow heads indicate processes of stellate cells extending into the bursal canal; thin arrow indicates the less definite epithelium of the bursal canal; white arrow indicates a piece of the corona of the cuticular apparatus of the bursa; black and white arrow indicates the connective tissue sheath which encloses the penis complex. Fig. 10. Everted penis complex of a living specimen; black and white arrow indicates the everted penis complex—note the ciliation of the atrial lining; arrow head indicates the distal tip of the penis stylet which is protruding from the penis complex. Photograph courtesy of Dr. Nathan Riser. Fig. 11. Living specimen, egg capsule with a four-cell embryo (black and white arrow). Abbreviations: acm, apical cell mass; ag, accessory gland; ast, attached sperm tube; at, genital atrium; avc, anterior vacuolated cells; b, cerebral ganglion; ba, bursa; bc, bursal canal; c, corona of the midpiece of the cuticular apparatus of the bursa; cab, cuticular apparatus of the bursa; dp, distal portion of the penis stylet; dtd, distal thickening of the dp; ec, egg capsule; f, funnel-shaped section of the midpiece of the cab; gs, glandular stylet; i, intestine; lrt, lateral rhammite tracts; ml, mid-loop of the penis stylet; mp, mouthpiece of the cab; mr, mouth rhammites; ov, ovum; p, pharynx; pc, penis complex; pp, proximal portion of the penis stylet; rg, rhabdite gland; rt, rhammite tracts; sc, stellate cell, vacuolated cells surrounding the cab; sm, spiral musculature surrounding the penis stylet; ss, sperm sac; ust, unattached sperm tube; vd, vas deferens; vg, vesicula granulorum.

*Holotype*. American Museum of Natural History (AMNH) No. 922.

*Paratypes*. AMNH Nos. 923, 924; Naturhistoriska riksmuseet (Stockholm, Sektionen för evertebratzoologi (SMNHI) Nos. 3083, 3084, 3085.

### *Epidermis*

The epidermis consists of closely-packed polygonal cells and is uniformly ciliated. The nuclei form a layer toward the inner margin of the epidermal cells, while a distinct layer, probably composed of ultrarhabdites, is evident toward the periphery. The nuclei are insunk (Hyman, 1951) only in the epidermis of the anterior 6% of the body (excluding the apex). The apex is covered by flattened cells without insunk nuclei.

There are numerous adhesive papillae (adhesive papillae type #1) which contain azocarmine-positive granules when stained with Heidenhain's "azan." These papillae have a three-humped appearance and are scattered over the entire body except for the anterior 6%.

In his work on turbellarian adhesive systems, Tyler (1976, 1977) demonstrated with electron micrographs the presence of two gland cells and one anchor cell associated with the adhesive organs of an unidentified species of *Paromalostomum* (the first record of this genus on the U.S. Atlantic coast). However, by serial reconstruction on the light microscopic level, only one gland cell and one anchor cell were detectable associated with the adhesive organs of *P. coronum*. Apparently, the anchor cell is located entirely within the epidermis. The gland cell can be divided into three parts: the cell body, the neck, and the papilla. The cell body contains the nucleus and is located at the level of the rhabdite glands. The neck extends up from the cell body through the anchor cell to the outside where the papilla is located. These adhesive papillae often are found closely associated with the rhabdites but they are not as numerous as the latter. This association of adhesive organs and rhabdites also was noted in *Paromalostomum* by Tyler (1976).

An apparent second type of adhesive papilla (adhesive papilla type #2) is present in the anterior 6% of total body length, especially at the sides of the apex. These adhesive papillae are not as numerous and are smaller than those found over the rest of the body. They stain yellow-orange with the "azan" procedure.

Adenal rhabdites (Hyman, 1951) are uniformly distributed over the animal, except for the anterior 6% of total body length (Figs. 5, 7). They are more or less curved, rod-shaped structures 12–18  $\mu\text{m}$  long and occur in bundles of up to 12 rhabdites. There is no apparent pattern to the distribution of either the rhabdites or their glands.

Numerous straight or slightly curved rhammites belonging to two size classes are present in the anterior body region and surrounding the mouth. The anterior rhammites (Figs. 1, 5) belong to the larger size class (15–25  $\mu\text{m}$  long). They are elaborated by numerous rhammite glands that are dorso-laterally located in the pharyngeal region and the region near the anterior one-half of the intestine. Obvious rhammite tracts (Figs. 1, 5) lead from the glands to the anterior tip of the body where the rhammites are grouped in numerous, closely

packed clusters. Two obvious lateral rhammite tracts break off from the rhammite glands at the pharyngeal-intestinal junction and pass anteriorly to the cerebral ganglion where they converge but do not join. The two tracts pass through part of the ganglion in this way but before leaving it, branch into as many as 12 tracts that pass anteriorly to the clusters of rhammites at the apex. These subepidermal tracts are closer to the dorsal surface than to the ventral.

Rhammites belonging to the smaller of the two size classes (5–7  $\mu\text{m}$  long) are heavily concentrated on the ventral side of the body surrounding the mouth (Fig. 7). These shorter mouth rhammites open into the pharynx close to the mouth and are elaborated by numerous rhammite glands that surround the pharynx at the pharyngeal-intestinal junction. Tracts of these rhammites extend from their glands to the mouth, passing ventro-lateral to the pharynx.

#### *Parenchyma and Body Musculature*

The subepidermal musculature is composed of fibers of circular muscles external to longitudinal muscle fibers. The parenchyma is more voluminous in the anterior and posterior ends (especially the anterior end). Relatively little is present in the mid-body region due to the extensive area occupied by the intestine and genital organs.

Groups of highly vacuolated cells with large nuclei totally envelop and extend beyond the cerebral ganglion and caudal nerve. The anterior group begins, on the average, 11% of total body length back from the apex and extends caudally as far as the mouth, thus occupying an average 7% of total body length. The posterior group occupies an average of 3% of total body length with its caudal end being less than 1% of total body length from the posterior end.

An apical cell mass which consists of numerous, compactly arranged secretory cells, extends anteriorly from the region of vacuolated cells for 8% of total body length, stopping, on the average, 3% of total body length behind the apex (Fig. 5). Some intermingling of apical cell mass and vacuolated cells occurs at the interface between the two regions of cells. The secretory granules of the cells of the apical cell mass stain deeply with azocarmine and also hematoxylin. Necks have been observed extending from these cells to the epithelium at the apex and, to a lesser degree, along the region of insunk nuclei. The anterior rhammite tracts pass through the central portion of the apical cell mass as do longitudinal muscle fibers. Occasional cyanophilous gland cells also are scattered throughout the body region anterior to the mouth.

#### *Nervous Tissue*

The nervous system, located in the parenchyma below the subepidermal musculature, is composed of a cerebral ganglion (brain) and two lateral nerve cords which extend posteriorly where they join to form the caudal nerve. Several nerves also extend anteriorly from the cerebral ganglion. The crescent-shaped cerebral ganglion (Fig. 4) is located 9% of total body length caudad from the apex and its longer dimension averages 150  $\mu\text{m}$ . The cell bodies of the cerebral ganglion are embedded in its outer periphery. In several prepa-

rations, a dividing wall is obvious down the center of the cerebral ganglion to give it a bilobed appearance. A horseshoe-shaped pharyngeal nerve extends as far as the pharyngeal-intestinal junction with the curved portion located just anterior to the mouth and the two sides lateral to the pharynx. A connecting loop between the two sides of this nerve to form a complete nerve ring was not seen in the light microscopic serial sections studied. The lack of a closed nerve ring is unusual in the Macrostomida (Doe, 1981). Electron microscopic observations are needed before completely ruling out the possibility of such a connection. The specific origin of the nerve is unclear but observations of several specimens indicate that it comes directly from the cerebral ganglion medio-posteriorly, which agrees with the observations of Doe (1981) for the nerve ring of *Paromalostomum* sp. No cell bodies were observed in association with the caudal nerve.

### *Digestive System*

The mouth (Figs. 1, 7) is located 13% of total body length back from the apex and can be expanded greatly to accommodate prey. The digestive tract consists of a simple pharynx, which averages 0.27 mm in length (14% of total body length), and a sac-like intestine, which averages 1.16 mm in length (55% of total body length).

The pharynx (Figs. 1, 7) is composed of a single layer of polygonal cells which possess short densely-packed cilia. It is surrounded by longitudinal and circular muscle fibers, that branch off of the body wall musculature. The longitudinal fibers surrounding the pharynx are more obvious than the circular muscle fibers by light microscopy. These longitudinal muscle fibers branch just anterior to the mouth and penetrate the apical cell mass. A band of circular muscles forms a sphincter-like structure at the pharyngeal-intestinal junction.

A dense glandular region surrounds the pharynx and extends caudad as far as the pharyngeal-intestinal junction. These unicellular pharynx-associated glands (Doe, 1981) are of two basic types: uniformly cyanophilous glands and the more numerous azocarmine-positive/basophilic glands which contain fine secretion granules. By electron microscopy, Doe (1981) was able to detect three types of associated glands in an unidentified species of *Paromalostomum*. Necks of both the azocarmine-positive/basophilic and cyanophilous gland cells have been observed emptying into the pharyngeal lumen along its entire length.

The sac-shaped intestine (Figs. 1, 7) is composed of ciliated simple columnar cells with basally located nuclei. Height varies from short cells lining a large intestinal lumen to very tall cells lining a tri- or quadripartite lumen. Such variation is due primarily to the amount and kind of intestinal content and/or the state of digestion. The granular contents of the intestinal cells also vary with the stage of digestion. The gut musculature is sparse.

### *Genital Complex*

*General aspects.* The common gonopore (Figs. 1, 2) is located ventrally approximately 86% of total body length caudad from the apex. The ciliated epithelium which surrounds it is unmodified.

The spacious genital atrium (Figs. 2, 10) extends dorsally from the gonopore about half-way into the bursa. The genital atrium is lined by an unmodified ciliated epithelium, which is continuous with that around the gonopore. The intra-bursal portion of the atrium is, in addition, surrounded by a thin amorphous cytoplasmic mass (Figs. 2, 10). The walls of the extra-bursal portion of the atrium are coated with fine secretory granules, which stain with azocarmine and hematoxylin. These deposits do not extend to the gonopore but are restricted to the atrial region.

The ciliated vagina, which is relatively short (no longer than 60  $\mu\text{m}$ ), extends from the genital atrium medio-rostrally (Fig. 2). A muscular sphincter occurs at the junction of the vagina and ovary. This connection is delicate and usually collapsed in sectioned material. The vagina is characterized by the presence of secretory deposits along its ventral wall and can be divided arbitrarily into three regions according to the nature of these deposits. The first 33% of its length (closest to the ovary) is free of secretion products. The next 47% of its total length is characterized by the presence of a coarse granular secretion which stains with azocarmine and with hematoxylin and is arranged in at least two distinct tiers. The last 20% of its length is characterized by the presence of the same fine granular secretion that surrounds the atrium. These two types of secretion (fine and coarse granular) are produced by two types of unicellular glands, the cement glands, which are located in the parenchyma ventral to the bursa in the region surrounding the gonopore. The first type of gland cell is abundant and is located in the region directly ventral to the bursa. These cells contain a fine granular secretion that is less than 1  $\mu\text{m}$  in diameter and stains both with azocarmine and hematoxylin. Necks have been observed extending from these cells to the epithelium of the atrium and the last 20% of the vagina. The less numerous, second type of gland cells are restricted to the ventral parenchyma immediately adjacent to the terminal ovum. They contain a coarse granular secretion that measures approximately  $2 \times 2 \mu\text{m}$  and stains with azocarmine and hematoxylin. Necks have been observed extending from these cells to the epithelium of the middle 47% of the vagina.

The oval bursa (Figs. 1, 2, 10), located 87% of total body length caudad from the apex, is enclosed by a connective tissue sheath. Its average dimensions are  $201 \times 166 \mu\text{m}$  (10%  $\times$  8% of total body length). Except for several clearly defined vacuolated cells, the bursa is composed of a mass of cytoplasm containing numerous nuclei, vacuoles, and cyanophilous, eosinophilous, and azocarmine-positive droplets of various sizes. Moreover, a portion of the genital atrium, the bursal canal, and the penis complex extend into the bursa.

The bursal canal (Figs. 2, 10) extends rostrally from the roof of the atrium and is attached at its terminal end to the cuticular apparatus of the bursa, which is connected to the ductus spermaticus and the latter in turn to the ovary. Thus, the ovary and common genital atrium are connected along two routes: (1) via the vagina; and (2) via the bursal canal. The ciliated epithelium that lines the atrium ends abruptly after extending into the bursal canal for a very short distance. The bursal canal is lined for the remainder of its course by a more diffuse epithelium, which (with the fixation procedures used) is

composed of scattered nuclei without evident cell bodies or membranes (Fig. 10). Furthermore, processes from cells surrounding the corona of the midpiece of the cuticular apparatus of the bursa extend down to the bursal canal, which is surrounded by a thick sheath of circular muscle.

The penis complex (Figs. 2, 10) is located dorsally, surrounded by the bursa. The complex begins at the entrance point of the ducts from the vesicula granulorum and accessory gland and extends for approximately 50% of the dorso-ventral span of the bursa where it joins the atrium. The ducts enter the bursa in close proximity and are lined by the walls of the penis complex for their entire length within the bursa. The penis complex is enclosed by a connective tissue sheath; it consists of a cytoplasmic mass that surrounds the male genital canal containing the penis stylet, and the glandular canal containing the glandular stylet. The cytoplasmic mass contains numerous nuclei but no clear cell membranes, and is continuous with the tissue that surrounds the intra-bursal portion of the genital atrium (Figs. 2, 10). The male genital canal and the glandular canal open into the genital atrium. The distal tip of the penis stylet is often pushed out into the atrium (Fig. 10). One living specimen was observed to evert the penis complex through the gonopore (Fig. 8). In this case, the distal tip of the penis stylet extended beyond the ciliated border of the more interior atrial lining, which was pushed out in advance of the penis complex itself.

*Male reproductive system.* The fusiform testis (Fig. 1), which is enclosed in a thin sheath, is ventral to the intestine toward the right side of the body and averages 374  $\mu\text{m}$  in length. Its anterior end is located 56% of total body length from the apex. Maturation of sperm occurs inwardly from the periphery of the testis. The vas deferens (Fig. 1) extends caudad from the testis for 19% of total body length. It expands slightly to form a false seminal vesicle just anterior to the true seminal vesicle (Fig. 1). The true seminal vesicle is medial and posterior to the bursa. It is surrounded by a muscular layer and averages 24  $\mu\text{m}$  in length by 24  $\mu\text{m}$  in maximum diameter. A short (ca. 10  $\mu\text{m}$  long) ductus intervesicularis connects the seminal vesicle with the vesicula granulorum (Fig. 1). The vesicula granulorum is posterior and dorsal to the bursa and averages 88  $\mu\text{m}$  in length by 46  $\mu\text{m}$  in width. It is surrounded by a thick (ca. 3  $\mu\text{m}$ ) layer of oblique muscle cells whose ovoid nuclei are located at the outer periphery of the muscle layer. Ciliated columnar cells of varying heights make up the body of the vesicula granulorum.

The penis stylet (Figs. 4, 6, 9) lies within the male genital canal. At its base, it is fused with the glandular stylet for a short distance. Totally extended, the penis stylet averages 178  $\mu\text{m}$  in length. It can be divided into two portions: (1) the twisted flexible proximal portion, and (2) the rigid distal portion.

The tubular proximal portion of the penis stylet averages 110  $\mu\text{m}$  in length; it is slightly thickened for an average length of 6  $\mu\text{m}$  at its extreme proximal end. That portion that is in contact with the glandular stylet is always found in the shape of an inverted "U." Distal to this region, the midsection of the proximal portion is fairly flexible, seen in many configurations from tightly twisted in a loop to fully extended. However, the extreme distal section of the stylet is folded into a distinct loop, the mid-loop of the penis stylet.

The rigid distal portion of the penis stylet averages  $68\ \mu\text{m}$  in length and possesses an additional layer of cuticular material around the tubular extension of the proximal part. There are two asymmetric thickenings of this additional layer at both ends. An indistinct end-hook is present at the extreme distal end. It is an extension of the tubular middle layer and is surrounded for only part of its length by the additional layer.

A strong muscular sheath surrounds most of the penis stylet. It is composed of a series of spiral muscles (Figs. 6, 10) that begin just above the proximal thickenings of the distal portion of the penis stylet and wind down around the proximal portion as far as the top of the inverted "U." In addition, a series of longitudinal muscles extends from the proximal thickening of the distal portion of the stylet through the well-defined mid-loop to the spiral musculature just below the end of the mid-loop. These longitudinal muscles may help to maintain the mid-loop in its folded position.

*Accessory gland.* The flask-shaped accessory gland (Fig. 1) is posterior to the bursa and averages  $139\ \mu\text{m}$  in length by  $112\ \mu\text{m}$  in maximum diameter. It is a blind sac, wide at the proximal end and tapering distally to a narrow duct that leads into the glandular stylet. No obvious musculature is associated with the accessory gland. It is composed of numerous columnar cells, some ciliated, some apparently not, which vary in height, shortening from the large blind end down to the narrow duct. These cells are arranged around a central lumen that extends distally to become continuous with that of the glandular stylet. Their large basal nuclei (up to  $7\ \mu\text{m}$ ) contain a large (up to  $2\ \mu\text{m}$ ) eccentric nucleolus. A single type of secretory granule is present within accessory gland cells. This is a spherical azocarmine-positive/basophilic granule that is slightly less than or equal to  $1\ \mu\text{m}$  in diameter. The gland can be divided into two regions according to the distribution of this secretion: (1) a very short distal secretion-free region (the narrow end), and (2) a much larger, proximal region filled with secretion (the wide, blunt end). The secretion granules are distributed differently within the cells of various specimens. The pattern of their distribution is of three basic types: (1) tight concentration around the lumen, (2) diffuse scattering throughout the cells, or (3) tightly packed, filling the entire cell. Also the lumen contained secretory granules in some specimens. No obvious correlation between the secretory composition and distribution and the stage of development of the female gonad, as was pointed out by Rieger (1971b) for *Paromalostomum fuscum* Ax, 1952, was seen in *P. coronum*. However, this may be due to the fact that specimens with immature female gonads were not sectioned for study. Long cilia are present on all of the cells composing the distal secretion-free region of the accessory gland, as well as on most of the cells composing the proximal region. The cilia of the accessory gland project into the glandular stylet.

The glandular stylet (Figs. 4, 6, 9) averages  $50\ \mu\text{m}$  in length and is connected to the accessory gland by a short duct  $24\ \mu\text{m}$  long. It is moderately bent, tapering gradually from the proximal to the distal end, and is located within the glandular canal adjacent to the male genital canal within the penis complex. The male genital and glandular canals branch out of a common canal at the base of the two stylets where the latter are connected. A series of circular

muscles surrounds the glandular canal for most of its length. Also, a series of oblique muscles extends from the sides of the glandular canal to the lining of the dorsal roof of the atrium. In addition, oblique muscles pass over the glandular stylet coursing from the thickenings at the proximal end of the penis stylet to the dorsal roof of the atrial lining.

*Female reproductive system.* The sac-shaped ovary (Fig. 1) is ventral toward the left side of the body with its posterior end 83% of total body length caudad from the apex of the animal. The ovary, averaging 578  $\mu\text{m}$  in length, is narrow and indistinct at its anterior end and widens at the posterior end which contains the largest, most mature ovum. The ova are arranged serially within the ovary and mature singly, increasing in size as vitellogenesis occurs. The nuclei of the ova undergoing vitellogenesis are in the germinal vesicle stage. The nucleus breaks down and the chromosomes are arrested in metaphase in mature ova. Coincidentally, bacillus-shaped azocarmine-positive/basophilic yolk granules of uniform size come to line the periphery of the ovum in a single layer. Evidently, this is the stage at which the ova are laid.

The ovary possesses a thin cellular lining, which is slightly elaborated at its caudal end into a loose, cytoplasmic tract (the caudal section of the oviduct, Rieger, 1971b). The tract joins the ovary with the vagina and ductus spermaticus and contains several large nuclei but no obvious cell bodies. The bulb-shaped ductus spermaticus (Fig. 2) is partly cuticularized and is enclosed by a connective tissue sheath. Enclosed within this sheath is a cytoplasmic mass containing several large nuclei. No separating cell membranes were obvious with the fixation procedures followed. The ductus spermaticus connects the mouthpiece of the cuticular apparatus of the bursa with the caudal section of the oviduct. The ductus spermaticus consists of a bulbous and a tubular region. The bulbous region lies entirely within the bursa on the ovarian side, on the average measures  $24 \times 21 \mu\text{m}$ , and contains most of the cytoplasmic mass forming the substance of the ductus spermaticus. Also, the terminal thickenings of the mouthpiece of the cuticular apparatus of the bursa are situated just within its distal tip. The cuticularized tubular portion extends from the proximal end of the bulbous portion to the caudal section of the oviduct and averages 18  $\mu\text{m}$  in length.

The cuticular apparatus of the bursa (Figs. 3, 6, 9) is located between the ductus spermaticus and the terminal end of the bursal canal; it consists of: (1) the mouthpiece, (2) the midpiece, and (3) the sperm tube(s). The mouthpiece, averaging 25  $\mu\text{m}$  in length, is an annulated tubule with the annuli less than 1  $\mu\text{m}$  apart. Two disk-shaped thickenings, averaging 7  $\mu\text{m}$  in diameter, are present at its terminal end. They are embedded in the ductus spermaticus and have a stellate appearance in transverse section. The mouthpiece joins with the midpiece at its opposite end. The midpiece is embedded in several clearly defined stellate cells whose processes extend to the bursal canal. It consists of a funnel-shaped section (10  $\mu\text{m}$  in length by 7  $\mu\text{m}$  in width), and an underlying corona (27  $\mu\text{m}$  in length by 10  $\mu\text{m}$  in width). The funnel-shaped section is joined to the mouthpiece and the corona, fitting over the corona at a point where it dips to form a slight concavity. The C-shaped corona also is joined to

the mouthpiece and is composed of a central rod with digitiform projections emanating from it. Two types of sperm tubes are present, attached and unattached. One type, both, or none may be found in a single animal. Generally, if only one type is present, it is the attached type. The attached sperm tubes are joined to the mouthpiece of the cuticular apparatus of the bursa and extend through the center of the funnel-shaped section of the midpiece. The unattached sperm tubes are free within the bursa. In mature specimens, up to two attached and/or unattached sperm tubes have been observed in a single animal. The sperm tubes measure up to 162  $\mu\text{m}$  in length. Sperm have been observed in a small sac attached to the distal end (Fig. 9), as well as in a large sac totally surrounding the tube (Fig. 6).

#### *Habitat*

*Paromalostomum coronum* lives in coarse sand in the low intertidal zone. At Griffith's Head Beach, a layer of peat that is moved by tide and wave action lies beneath the sand. Thus, the peat was covered by 0–5 cm or more of sand at the various collecting times. *P. coronum* was abundant in the samples taken there, usually being the dominant metazoan. A variety of fauna was sorted from the sand with *P. coronum*, including representatives of such groups as acochlideans, polychaetes, oligochaetes, nemerteans, and other turbellarian genera. Those forms routinely encountered in significant numbers include the kalyptorhynch turbellarian *Cystiplana rubra* Dean, 1977, the polychaete *Microphthalmus listensis* Westheide, 1967, and the acochlidiacean gastropod *Unela nahantensis* Doe, 1974.

#### *Behavior*

*General.* When disturbed, *Paromalostomum coronum* assumes a somewhat spherical appearance by retracting the anterior 6% of its body. *P. coronum* seems to be gregarious and congregates on the side of the fingerbowl opposite a light source, as do the copepods on which they feed. *P. coronum* also aggregated with an unidentified species of *Trilobodrilus* when maintained in unsorted collections from Manomet, Massachusetts.

*Feeding.* *P. coronum* is a voracious predator, feeding on copepods, *Artemia* nauplii, nematodes, and polychaetes. However, they were never observed to feed on the species of *Trilobodrilus* with which they were associated. The only time that the actual capture process was observed, a specimen used its anterior end to first butt, then push a copepod into its mouth (Riser, personal communication). Several specimens were observed holding a copepod or *Artemia* nauplius in their pharynx and slowly drawing it tail-first into the gut in spite of the violent activity of the prey.

#### *Life Cycle*

Periodic collections were made from August 1975 to March 1977; mature specimens were found throughout the year. Very often, sexually mature adults and small juveniles were taken from the same sample. Eggs were deposited in glass fingerbowls in the laboratory from October 1975 to March 1977 at am-

bient sea-water temperature. Thus, reproduction (at least in the laboratory) is not seasonal as was reported for *P. fusculum* by Pawlak (1969), but apparently occurs in *P. coronum* as soon as the animals reach a certain age or size, provided that an adequate food supply is available. Thus eggs are being laid continually, and juveniles and adults are present in the population at all times. Eggs are deposited singly in the one-cell stage in nearly spherical egg capsules that measure  $250 \times 200 \mu\text{m}$  and lack a sharply defined operculum. The egg capsules are strongly cemented to the glass fingerbowls, appear white by reflected light, and yellow-brown by transmitted light. At the two- and four-cell stage (Fig. 11), the individual blastomeres are equal in size. However, beyond the 32-cell stage some blastomeres are larger than others, although the size difference is not great.

Development of *P. coronum* is direct. During late fall and spring, eggs hatch after approximately 30 days. One egg deposited in late October, however, hatched after only 12 days. The juveniles emerge from the capsule lacking genital organs, but with a clearly defined gut and pharynx, and some rhabdites—but apparently not a full complement of rhabdites. The smallest juvenile of *P. coronum* observed measured  $350 \mu\text{m}$  in length and its age was unknown. The maximum length of two juveniles measured within 20 h of hatching were  $400 \mu\text{m}$  and  $520 \mu\text{m}$ . I was not able to maintain the juveniles for longer than a few days in the laboratory.

#### DISCUSSION

The data presented by Rieger (1977) on one species of haplopharyngid and seven species of macrostomid turbellarians (including several species of *Paromalostomum*) substantiates the validity of using copulatory structures as a diagnostic feature for species recognition in these groups. His data suggests that spatially separated populations show no significant differences in overall stylet shape, although total length may vary to some degree with geographical distance (Rieger, 1977). However, members of the family Dolichomacrostomidae show less variation in length than members of the family Macrostomidae (Rieger, 1977). *P. dubium* Beauchamp, 1927, *P. atratum* Rieger, 1971, and *Paromalostomum* sp. showed little variation in overall shape and size, both within and between spatially isolated populations (Rieger, 1977). Thus, the unique form of the cuticular pieces (penis stylet, glandular stylet, and cuticular apparatus of the bursa) of *Paromalostomum coronum* make it possible to readily distinguish this species.

Variation in the shape of the penis stylet of the species of *Paromalostomum* centers around the shape of the thickenings on the distal portion and the size and extent of the end-hook. The penis stylet of *P. coronum* is similar to that of *P. dubium*, *P. parvum* Rieger, 1971, and *P. massiliensis* Rieger, 1971 in that all of these possess a short end-hook and obvious distal thickening. It differs from those of *P. fusculum*, *P. minutum* Rieger, 1971, *P. proceracauda* Pawlak, 1969, *P. atratum*, and *P. subflavum* Sopott-Ehlers & Schmidt, 1974 in their possession of a long distinct end-hook. In addition, *P. proceracauda* differs in

its possession of a reduced distal thickening, and *P. subflavum* and *P. atratum* differ in their lack of a distal thickening.

The glandular stylet of *P. coronum* is similar to that of *P. fuscum*, *P. parvum*, *P. massiliensis*, and *P. minutum* in being slightly bent and tapering distally to an open point. It differs from *P. dubium* and *P. subflavum* since their glandular stylets flare out at their tips; it differs from those of *P. atratum* and *P. proceracauda* in that their glandular stylets are sharply bent into a characteristic hook.

If one compares the length of the distal portion of the penis stylet with that of the glandular stylet, they are approximately the same length in *P. coronum*, with the distal portion of the penis stylet being slightly longer on the average than the glandular stylet. This approximate 1:1 size ratio between these two cuticular stylets in *P. coronum* is similar only to *P. subflavum* and differs in this respect from the remaining seven species of *Paromalostomum*. In these species, the glandular stylet is longer (up to 2.5 times longer) than the distal portion of the penis stylet.

The form of the mouthpiece and attached sperm tube of the cuticular apparatus of the bursa is similar in all species of *Paromalostomum* (including *P. coronum*) and varies only in size. The midpiece of the cuticular apparatus of the bursa of *P. coronum* is unique among the currently described species of the genus due to the extensive development of the "corona"—the C-shaped rod with digitiform projections. However, the funnel-shaped portion of the midpiece of *P. coronum* is similar to that of *P. atratum*, *P. parvum*, *P. massiliensis*, and *P. minutum* in that all are basically a funnel with a more or less triangular lobe attached to its mouth. The midpiece of *P. coronum* differs from that of *P. fuscum* in that the midpiece of this species has a sharply coiled lobe attached to the mouth of the funnel, and from those of *P. proceracauda* and *P. dubium* because their midpieces are more bowl-shaped; *P. proceracauda* lacks the attached lobe. Finally, the funnel-shaped section of the midpiece of *P. coronum* differs from that of *P. subflavum* in its spherical shape, bilobed structure, and distal furrow enclosed by circular muscles.

Prey for only five of the remaining eight species of *Paromalostomum* has been reported (Pawlak, 1969; Rieger, 1971b) and is similar but not identical to that of *P. coronum*. *P. fuscum* and, in one instance, *P. atratum* have been reported to feed on detritus, foraminiferans, remains of tardigrades, copepods, ostracods, and nematodes. *P. dubium*, *P. minutum*, and *P. proceracauda* have been observed feeding on nematodes.

The development of only two other species of *Paromalostomum*, *P. fuscum*, and to a lesser degree, *P. dubium*, has been studied (Pawlak, 1969). *P. fuscum* and *P. dubium* also have direct development and deposit their eggs singly in approximately spherical egg capsules. Their capsules are smaller in diameter, 159 and 139  $\mu\text{m}$ , respectively, than those of *P. coronum*. Cleavage stages were not described for *P. fuscum* or *P. dubium*. The egg capsules of *P. fuscum*, like those of *P. coronum*, are strongly cemented to the substrate, while those of *P. dubium* are reported by Pawlak (1969) to be less tightly

cemented. *P. fusculum*, however, differs greatly from both *P. coronum* and *P. dubium* in having a clearly defined operculum on the egg capsule (Pawlak, 1969). The size range for the juveniles of *P. coronum* (350–530  $\mu\text{m}$ ) approximates that of the juveniles of *P. fusculum* (280–400  $\mu\text{m}$ ) (see Pawlak, 1969). The appearance of the juveniles of *P. fusculum*, upon emergence from the egg capsule (Pawlak, 1969), is similar to that reported here for *P. coronum*. Pawlak (1969) did not describe the juveniles of *P. dubium*.

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### Phycological Society Awards

The Phycological Society of America sponsored two awards at the recent 34th Annual AIBS Meetings held at the University of North Dakota, Grand Forks. The recipient of the 1983 Harold C. Bold Award was F. Gerald Plumley from the University of Georgia, Athens, who won the best student paper presentation entitled "Selective accumulation of photosynthetic proteins in *Chlamydomonas reinhardtii* (Chlorophyceae) following pulsed additions of nitrogen." The winner of the 1983 Gerald W. Prescott Award was Matthew J. Dring, Queen's University of Belfast. The first biennial award was presented by Dr. Prescott in recognition of the outstanding scholarly book or monograph devoted to algae. The title of Dr. Dring's book is "The Biology of Marine Plants," published by Edward Arnold. DEAN W. BLINN, Chairman, G. W. Prescott Award and H. C. Bold Award Committees.