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H. F. Wickham

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UNIVERSITY OF IOWA STUDIES IN NATURAL HISTORY

HENRY FREDERICK WICKHAM, Editor

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CONTENTS

A STUDY OF TRITOGONIA TUBERCULATA, THE PISTOL-GRIP MUSSEL

David T. Jones

The incentive to study certain animals comes, not because of their utility, but because their uniqueness arouses curiosity. The blade-beaked skimmers (Rhynchopidæ), duck-billed platypus (*Ornithorhynchus*), the dog's head butterfly (*Zerene cæsonia*) are familiar examples. Among mollusks, the buckhorn or pistol-grip, *Tritogonia tuberculata* (Barnes), likewise never fails to arouse curiosity. Children wonder "what is the matter with it" and usually regard it as a freak. The noticeable feature about the shell is the surface, studded with protuberances which makes the name "pistol-grip" applicable. Call speaks of the surface as "nodulous," while Baker calls the prominences "tear-like pustules." Simpson[1] regarded this shell as peculiar enough to merit a separate genus *Tritogonia*. Ortmann[2] thinks it resembles the Quadrulas enough in internal anatomy to be called *Quadrula tuberculata* (Barnes). As to the pustulate surface, he calls attention to the fact that *Quadrula lachrymosa* (Lea), the maple-leaf is scarcely less pustulose. Walker,[3] however, as late as 1918, is content to let it remain aloof in its own genus *Tritogonia*.

Simpson gives two species and one variety of *Tritogonia* for the United States. In distribution *Tritogonia tuberculata* is confined to the Mississippi Valley and Gulf drainages. Call[4] gives its range as "Western New York to Minnesota, Iowa and Nebraska; to Kansas and central Texas; to Georgia and Alabama. The species was originally described from Wisconsin." In most older works it goes under the name *Unio tuberculatus* (Barnes), which name dates from 1823.

Economic reports on *Tritogonia tuberculata* for the most part consider it along with other shells. It is used to a certain extent

[1] Synopsis of the Naiades, p. 608.

[2] Families and Genera of the Najades, p. 254.

[3] A Synopsis of the Classification of the Fresh Water Mollusca of North America, p. 45.

[4] The Unionidæ of Arkansas, p. 55.

in the pearl-button industry. Coker[5] reports it as having "white nacre of good texture and quality, but is often spotted. It is thinnish at the tip and has a very rough back; some shells have a pinkish tinge." Baker[6] reports that the Salt Fork and Sangamon species (Illinois) are of good quality for buttons, and calls attention to the fact that "abnormalities and pearly growths due to injuries or parasitism are rare in specimens of this species examined." Call reports the nacre as usually white, but often blotched in large specimens with irregularly distributed, brownish spots. He says that more than half the specimens from the Cahaba River, Alabama, have purple nacre.

The following extracts from descriptions bring out the main features of the shell and animal.

Ward and Whipple[7]—"All four gills serving as marsupia. Shell large, solid, rhomboid, truncated posteriorly in the male, elongated with a strong posterior ridge, sexes dissimilar in shape, the posterior region being rounded or subcompressed in the female; hinge complete, surface pustulose, except on the extended portion of the female." Walker—"Epidermis dark olive, hinge plate rather narrow; pseudocardinals strong, rugged; laterals long and straight, near to the pseudocardinals." Simpson—"Well developed lunule filled with epidermal matter. . . . . Inner gills much larger than outer, generally free from abdominal sac."

The periostracum is thin and tough, not scaling readily; the prismatic layer thin, and the nacreous layer thick. All three layers enter into the composition of the nodules. On the inside of the shell the nacre is smooth showing no conformity to the rough exterior except slight undulations in the posterior region, and an arched furrow corresponding to the umbonal ridge. The latter is sometimes so great as to pull the mantle away from the shell, thus breaking the pallial line as in fig. 3. The nodules are irregular, but often elongate and pointed radially in the opposite direction from the beak. Back of the posterior umbonal ridge especially of the short shells, the nodules are extremely large and united in huge folds.

A good start has been made on the ecology of *Tritogonia tuberculata* in the Fisheries Bureau Report on "Natural History and

5 Fresh-water Mussels and Mussel Industries, p. 27.

6 Fauna of the Big Vermillion River, p. 33.

7 Fresh Water Biology, p. 998.

Propagation of Fresh-Water Mussels[8]." There *Tritogonia tuberculata* is recorded as being found in sand, sand and gravel, gravel, mud and sand, soft mud over firm bottom, mud, and clay and sand. Authorities disagree as to which kind of bottom *Tritogonia tuberculata* prefers, some believing "mud" or "mud over firm bottom", while others believe "gravel". Drew[9] records it as common, especially on muddy bottoms. Baker found the largest specimens "on a mud bottom although it also lives on sand and gravel bottom." The specimens on which this article is based were brought up by the sand pump from the sand bed in Iowa River just south of Benton Street bridge at Iowa City, Iowa. Somewhere in the neighborhood of fifteen specimens were secured during the period from September through December, 1925. When rock and gravel were pumped up with the sand they seemed to be the most plentiful. They were thrown out very irregularly, more than half the number being secured on two days between which several weeks intervened. As the intake of the sand pump was swinging across the river in ever-lengthening arcs, this would hint at gregariousness. Single specimens were secured while the pumping was confined to the middle of the stream, but the two groups were struck when pumping was approaching shore, yet in deep water and current. Coker, Shira, and co-workers record *Tritogonia tuberculata* as occuring in little or no current, fair or good current, and strong or swift current. Two authorities think it prefers the second situation; one, the last. While *Tritogonia tuberculata* seems to prefer a current, it can live in still water. Of the group on which this article is based, one was kept alive from the latter part of September to the first of the following December in a vessel in which the water was changed once a day or once in two days. *Tritogonia tuberculata* outlived other species (*Quadrula plicata, Q. pustulosa,* and *Lampsilis gracilis*) kept under similar conditions. Of the other forms *Quadrula plicata* seemed to approach the endurance of *Tritogonia tuberculata.*

As this study was made in the fall there was no opportunity to observe glochidia for *Tritogonia tuberculata* is a summer breeder.[10] Simpson, quoting Kelly, in "Synopsis of the Najades" says that

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[8] Coker, Shira, Clark, and Howard, p. 106.

[9] Unios of Iowa, Vol. 2.

[10] Coker and others. Natural History and Propagation of Fresh Water Mussels.

the form with the compressed shell, having the expanded flap behind, is the female. Very little seems to be known of the life history of this species. Coker, Shira, and associates give an illustration of a glochidium, and observed the growth made by a medium sized specimen from July 31, 1911 to Nov. 14, 1913 during which there was an increase in length of 0.36 inch. Baker, in Salt Fork at Homer Park, Ill., found large males 115 mm. long and females 145 mm. long, together with young specimens 46 mm. long.

Tritogonia tuberculata has been and is yet reported as common in regard to numbers throughout its range. In the region of Iowa City the following are the most common mussels in the order of their abundance, judging from what the sand pumps throw up and from the shell piles along the shore.

1. Quadrula plicata (*Q. undulata* is less common than *Q. plicata* and is usually not distinguished from it.)
2. Symphynota complanata
3. Lampsilis gracilis
4. Lampsilis ligamentina
5. Anodonta grandis
6. Quadrula pustulosa
7. Tritogonia tuberculata
8. Lampsilis ventricosa
9. Lampsilis anodontoides
10. Obliquaria reflexa
11. Plagiola donaciformis
12. Lampsilis alata
13. Quadrula trigona
14. Lampsilis capax
15. Pleurobema æsopus
16. Quadrula coccinea
17. Lampsilis recta—1 live specimen and 1 valve found
18. Quadrula metanevra—1 specimen—Coralville
19. Lampsilis subrostrata—1 specimen—near Amana
20. Quadrula ebenus—1 valve
21. Quadrula lachrymosa?—1 valve.

The following living mussels were thrown out of the same sand bed where the specimens of *Tritogonia tuberculata* were secured. These are given in the order of their abundance.

1. Quadrula plicata
2. Lampsilis gracilis

3. Anodonta grandis
4. Quadrula pustulosa
5. Tritogonia tuberculata
6. Lampsilis anodontoides
7. Quadrula trigona—1 specimen
8. Pleurobema æsopus—1 specimen.
9. Symphynota complanata—1 specimen.
10. Lampsilis recta—1 specimen.

Shimek's "Keys to the Mollusca of Iowa" were used in classification. Drew's "Unios of Iowa" Vol. 2, Coker's "Freshwater mussels and the mussel industries of the United States" and other articles were used as checks on identification.

I wish to thank Dr. Gilbert L. Houser and Dr. Frank A. Stromsten for the facilities provided in the laboratories of Animal Biology of the State University of Iowa where this study was made, as well as for the helpful suggestions offered.

Tissues for sectioning[11] were fixed in Bouin's picro-formol, Carnoy's fluid, Chrom-aceto-formaldehyde,[12] and Chrom-oxalic acid.[13] The paraffin method for delicate objects was used. All sections were cut 10 micra thick except one thick free-hand section through the edge of the mantle to show the calcareous bodies in the connective tissue. For a detailed study of cell structure it would be better to cut still thinner. Sections through the visceral mass were floated out in warm water immediately after cutting to prevent curling. Delafield's hematoxylin and erythrosin were used as stains, although mucin tests were made with thionin also. The calcareous nature of structures was tested by adding glacial acetic acid to freshly-stained sections and observing changes under the low power of the compound microscope. Permanent sections were cleared in

[11] See Guyer for technique unless specifically stated.

[12] Formula used in Laboratories of Animal Biology, S. U. I.

Chromic Acid, 1%	640 cc.
Glacial Acetic	40 cc.
Pure Formaldehyde	320 cc.
	1000 cc.

Wash out in water.

[13] Formula used in Laboratories of Animal Biology, S. U. I.

Oxalic Acid, 8% aq. sol.	800 cc.
95% Alcohol	600 cc.
Chromic Acid, 1% aq. sol.	600 cc.
	2000 cc.

Mix in the order as named.

xylol and mounted in balsam. Outlines of drawings of microscopic sections, except figures 8, 9, 14, and 21 were made by the aid of the projecting microscope. Figures 8, 9, and 14 were made under oil immersion.

The ligament in *Tritogonia tuberculata* extends from the beaks posteriorly about half the length of the hinge teeth. It is low, usually not rising above the level of the dorsal part of the valves. Anterior and posterior to the ligament lie the anterior and posterior lunules respectively. The former has more epidermal matter and is better developed. Both lunules and the ligament have a heavy outer layer corresponding to the periostracum of the valves.

The interior of each valve, if normal, is a mirror-image of the other, except for the teeth. The cardinal teeth, normally two in each valve, are large and jagged, the most anterior cardinal in the left valve being usually largest. The broad, smooth, flattened junction between the cardinals and hinge teeth is well developed in both valves. On the right valve it frequently bears a rudimentary third cardinal. There are two hinge teeth in the left valve and one tooth in the right. Of the former, the ventral tooth is usually highest in its posterior extent. The hinge teeth are quite straight but do not run parallel with the dorsal border of the shell.

Both anterior and posterior adductor scars are well impressed, the former being deeper. Continuous with its inner border is the scar of the anterior retractor pedis. The impression of the protractor pedis, immediately posterior to the anterior adductor, is especially deep. The posterior retractor pedis scar, near the dorso-anterior border of the posterior adductor, is very superficial.

The pallial line normally extends from the lower outer portion of the anterior adductor scar around to the outer border of the posterior adductor scar. It does not run parallel to the border, especially in the posterior part, but continues its oval course without following the posterior bulge of the margin. Some mantle vessel, probably the peripheral artery of the mantle, has impressed a groove in the nacre, starting where the pallial line meets the anterior adductor scar, then curving outward and running posteriorly close to and parallel with the margin of the valve. This groove becomes fainter as it proceeds posteriorly. A slight pearly ridge, obliquely dorsal to the depression which corresponds to the umbonal ridge is noticeable in some shells.

The mantle closely invests the inner surface of each valve. It is attached at the muscle scars by the piercing strands of the muscles, and at the pallial line also by muscular strands. The mantle is thin and barely transparent except the portion distal to the pallial attachment, which forms a thickened muscular edge. The right and left lobes of the mantle are fastened together between the two siphons in the region of the posterior termination of the gills. At the exhalant siphon there is little modification of the mantle, but at the inhalant the margin is much thickened, and the inner part is modified into papillæ, called siphonal tentacles or fimbriæ. These are most robust near the center of the siphonal opening. There are from seven to fourteen large fimbriæ on each side of the siphon and twice that many small ones. The two lobes of the mantle meet near the posterior ends of the hinge teeth. A thickened fold of the mantle (fig. 4x) lying dorsal to the hinge teeth continues as thin sheets over the hinge teeth of both right and left valves. Between the bases of the cardinal teeth the mantle is thickened, and again becomes very thin over the jagged portion of the cardinals.

The function of the mantle in secreting the shell is an interesting study. The edge of the mantle is modified, not only at the inhalant siphon, but to the lesser degree all around. In cross-section it shows an outer, a middle, and an inner lobe (fig. 11). The periostracum is secreted from a groove at the junction of the outer and middle lobes. This groove is lined ventrally by a mound of tall columnar epithelium and dorsally by cuboidal epithelium (fig. 13). The periostracum seems to come off of the latter as a secretion. The cells of this groove are not pigmented as is the neighboring epithelium. This apparatus makes an excellent histological study. Without using a lens the periostracum can be seen stretching over the outer fold to the edge of the valve, in specimens where the mantle has been undisturbed. The origin of the prismatic layer and nacreous layer is not so evident. Since the periostracum is the outer layer, and is laid down first, the other two layers would have to be formed by the outer lobe of the edge or the outer epithelium of the mantle. No histological evidence was found as to the origin of these two. Parker and Haswell make the statement that the prismatic coat is also formed by the edge of the mantle and the nacreous coat by the whole outer surface of the mantle. The outer epithelium consists of tall columnar epithelial cells (fig. 14) resting on a homogeneous basement membrane under which are the muscle cells and connective tissue. The inner epithelium is similar but contains more mucous cells, many of which are subepithelial (fig. 12). The inner lobe of the edge of the mantle contains much amorphous material which stains blue with hematoxylin. In the middle, connective-tissue layer of the mantle, large masses of granules calcareous in nature were found. These disintegrate least in thick sections.

A process, no less interesting than the activities of the mantle edge, is going forward in the region of the hinge teeth and cardinal teeth. Drew, in "Unios of Iowa", Vol. 1, gives sections through the teeth, showing the undulating layers of nacre deposited by the mantle. Coker and co-workers, in "Natural History and Propagation of Fresh-Water Mussels", say that hypostracum is laid down by the ends of the muscles in place of nacre. Since the muscles retain the same relative position on the shell during the life of the animal they must migrate to keep up with shell growth. Thus a layer of hypostracum extends in a tapering vein through the nacre from the beak to each muscle scar and to the pallial line. Considering the process of enlargement of the teeth by the mantle as going forward over these earlier deposits of hypostracum, the explanation of the growth of this part of the shell becomes as interesting as the marginal growth. It is interesting to note that the thickest part of the mantle, which is in the region of the inhalant siphon, produces the thinnest part of the shell. A fold of the mantle, covering the anterior ends of the gills and the liver, is contained in the umbonal cavity which in *Tritogonia tuberculata* lies under the flattened junction of cardinal and hinge teeth.

The outer gills are attached to the mantle. Keber's organ, a light brown body, lies along the mantle dorsal to the junction. The gills are generally considered as modified folds of the mantle. There are four gills, one pair on each side of the central, visceral mass. The outer gill in *Tritogonia tuberculata* is much shorter than the inner one, as shown in fig. 5. Each gill is composed of two lamellæ with an intervening series of water tubes. The lamellæ are connected by interlamellar junctions between water tubes. Each lamella is finely striated vertically on its outer surface by ridges and grooves. These ridges are the gill filaments. There are ten to the millimeter in one specimen studied. In this specimen, interlamellar junctions showed through the lamella so they could be counted from the outside. There were twelve of these to one centimeter. Fig. 17 shows a cross section of the dorsal portion of the gills. The filaments cut in section are margined with ciliated epithelium. Spaces, called ostia, open between filaments and communicate with the water tubes. Thus water, admitted through the inhalant siphon, circulates from the mantle cavity through the ostia, through water tubes, to super-branchial chamber, and out at the exhalant siphon. Through the substance of the lamella and interlamellar junctions run many blood vessels. Schwanecke, in 1913, worked out the relations of these vessels in *Anodonta*. He finds that the venous net or reticulum lies vertically near the outer edge of the lamella and extends into each gill filament. The arterial net is represented by a vertical network of vessels near the water tubes. Between these two nets there are connectives. The larger arteries come in through the interlamellar junctions. Supporting rods are found in the filaments. In the dorsal portion of the gill, mucous material was found. Masses of mucous material seem quite common in the mantle and certain parts of the body. Sometimes they are amorphous, sometimes goblet cells, or long subepithelial mucous cells. The last case is best illustrated in the long subepithelial mucous cells in the ventral portion of the foot (fig. 16).

The visceral mass consists of two parts;—the visceral mass proper and the muscular foot which curves over the visceral mass ventrally and anteriorly. The foot in the *Tritogonia tuberculata* is narrower and projects more anteriorly than the foot in mussels of the *Lampsilis* type. A specimen kept in an aquarium quickly buried itself in the sand on the bottom when the water became stagnant, instead of pulling itself over the surface as *Lampsilis gracilis* and *Quadrula plicata* did. The foot in *Tritogonia tuberculata* seems to be very efficient, although it is less frequently protruded than in the Quadrulas. Above the foot is the visceral mass proper which in cross-section projects downward in longitudinal midline into the foot (fig. 21). Transverse muscles pass through the visceral mass from the muscles of the foot on one side to those on the other. Most of the visceral mass proper is composed of reproductive organs which give it a spongy appearance. In the visceral mass are imbedded parts of other systems as described below. Dorsal to the visceral mass lie the organs of Bojanus, kidneys or nephridia, two tubes one on each side consisting of a ventral glandular and smooth dorsal portion. They lie just dorsal to the internal gill and lower, more internal, and more posterior than Keber's organs (fig. 4). A section through the folds of the glandular portion (fig. 15) shows that these folds are made up of a single layer of columnar epithelium, beneath which is a thin layer of connective tissue. Under this are large spaces containing many leucocytes.

Dorsal to the organs of Bojanus, and in midline, is the heart, composed of a tubular ventricle and two flaplike auricles (fig. 4). The ventricle is folded around the rectum, thus enclosing it. The pericardium (fig. 5) covers this organ loosely leaving a large pericardial space.

The nervous system consists of three pairs of ganglia. In *Tritogonia tuberculata* the nervous system is white. In two of the species dissected, namely *Symphynota complanata* and *Pleurobema æsopus*, this system had a salmon colored tinge which set it off markedly from the surrounding tissues and facilitated dissection. In *Tritogonia tuberculata* the cerebral ganglia lie on the ventro-posterior surface of the anterior adductor muscle, the visceral ganglia on the ventral surface of the posterior adductor, and the pedal ganglia in the muscles of the anterior foot region in midline near the junction of the visceral mass proper with the muscles of the foot (fig. 4). The first two pairs are connected by commissures (fig. 21) and the pedal are connected to the cerebral ganglia by commissures. In a cross-section through the pedal ganglia and anterior foot region, the nerve cells were torn apart in sectioning by transparent, elongate capsules, which were themselves shattered by the razor. Some of these contained coarse, granular bodies which stained deep blue with hematoxylin. These parasitic sporocysts (fig. 9) seemed to be confined to the ganglia as the surrounding muscles were free of them. Except for lacking the long flattened tail, they resemble the sporocysts of gregarines which Helen P. Goodrich illustrated in a recent number of the Quarterly Journal of Microscopical Science.[14]

The labial palps are four in number and lie one pair on each side of the visceral mass. They are joined dorsally for a greater part of their length. The approximated sides of labial palps are furrowed vertically by lateral furrows (figs. 6, 7, and 10). These furrows and the ridges between are lined with columnar, ciliated

[14] Quarterly Journal of Microscopical Science. Vol. 69, Part IV, Oct. 1925, Plate 49, page 628, fig. 10.

epithelium which rests on connective tissue. Grooves project into the ridges on either side of the furrows. These grooves are very regularly arranged in *Tritogonia tuberculata*. Many blood vessels run through the connective tissue of the palp. The outer epithelium rests on a heavy basement membrane of homogeneous structure. The labial palps are united and fastened to the visceral mass for about one-half their length as shown in figure 5. However, the labial palps are joined together posterior to this and are attached to the mantle for about five-sixths of their length, the posterior one-sixth being free. In this region, where they are joined to the mantle but not to the visceral mass, there is a distinct dorsal furrow which extends dorsally to the ventral margin of the inner gill. This furrow is lined with columnar epithelium (fig. 8) which has very large cilia. Many goblet cells also occur in this region. The two pairs of labial palps meet at the mouth, thus forming upper and lower lips.

The mouth opening is small. It leads into a short esophagus which gradually enlarges and opens to the right into a sac-like stomach which continues as a blind pouch anteriorly. Both esophagus and the stomach are surrounded by the liver. The intestine leads obliquely, from the ventral part of the stomach, in a U-shaped loop ventro-posteriorly through the mass of reproductive organs to the ventral part of the visceral mass proper, then curving dorsally to the postero-dorsal portion of the visceral mass. This U-shaped portion is sometimes called the crystalline style portion, as under certain conditions it contains the crystalline style. From here the intestine bends sharply on itself, curving to the right and posteriorly. It descends parallel to the ascending ramus of the U until it reaches the most ventral portion of the visceral mass; thence it continues anteriorly along the ventral margin of the visceral mass until under the stomach, then curves sharply on itself, turning to the right and running posteriorly, crossing to the right of the descending ramus of the U. This part is known as the thin-walled portion. After crossing to the right it curves between the two rami of the U as the rectum, and passes into the pericardium and the ventricle of the heart where it takes a horizontal course posteriorly, finally running dorsal to the posterior adductor and terminating in the anus which is bordered by scalloped folds. Starting in the last ascent of the intestine, or in the rectum, is a ventral fold, the typhlosole. The intestine is small in the crystalline style portion. The thin-walled portion and rectum are much more enlarged. The coiling of the intestine is remarkably uniform in the different species of mussels examined. Variations were noted in *Tritogonia tuberculata* in the anterior extent of the intestine in the ventral portion of the visceral mass, and in the nearness of approach to the stomach of the typhlosolic portion of the rectum (fig. 4).

A cross-section of the rectum in the region of the ventricle (fig. 20) shows an inner lining of ciliated, columnar epithelium with many goblet cells. The typhlosole is composed of connective tissue. The basement membrane of the epithelium is most pronounced here.

The liver, greenish in color, closely surrounds the esophagus and stomach and extends dorsally with the anterior portion of the gills into that fold of the mantle which goes into the beak of the shell (fig. 4). It is a compound tubular gland as shown by cross-section (fig. 18). The larger ducts are lined by folded epithelium composed of slender, ciliated, columnar cells and goblet cells. Some of these folds are caused by actual folding while others are formed by elongation of the cells. The tubes are lined with secreting epithelium, composed of large cuboidal or columnar cells.

Tritogonia tuberculata structurally presents a peculiar shell, some peculiarities of the gills, and a narrower and more anteriorly projecting, blade-like foot than most freshwater mussels. It is hardy, it can endure still water, and is of some economic value. This combination recommends further investigation of its life history from the viewpoint of mussel culture. Dr. Frank A. Stromsten suggests that an investigation of the correlation between lime content of water and type of shell might be well worth while in the transplantation of mussels. It would be interesting to have data from certain parts of Iowa where streams flow over relatively little limestone, and then similar data from limestone regions of our state, and notice the difference in thickness and texture of the shells of mussels from the two areas. Professor Shimek finds snail collecting better in limestone regions than in sand dune areas, even though the latter be wooded. Some similar correlation might be found in mussel distribution. Mr. George Potter brought some mussels from the Okoboji and Little Sioux regions, an area of comparatively little limestone and near the headwaters of the drainage systems. I notice that his specimens of *Symphynota complanata* are much more fragile than those we find here in the Iowa River. The number of species varies with different localities, and the individuals of one species vary likewise with locality. The whole question is one that calls for data which could be collected easily.

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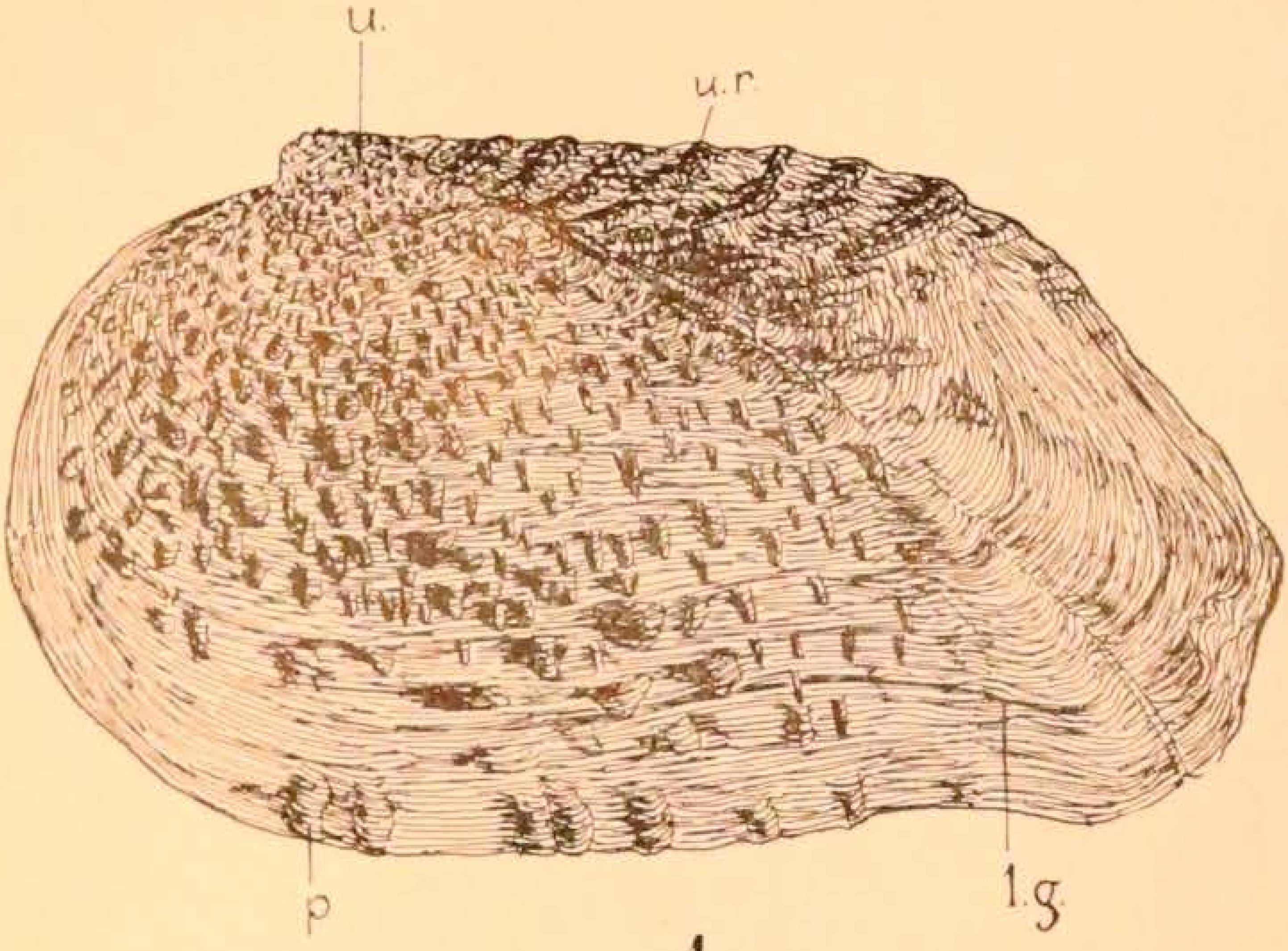
PLATES

PLATE I

Key to figure 1. Elongate form of *Tritogonia tuberculata*
u. umbo
u.r. umbonal ridge
p. pustule
l.g. line of growth

Key to figure 2. Short form of *Tritogonia tuberculata*
l. ligament



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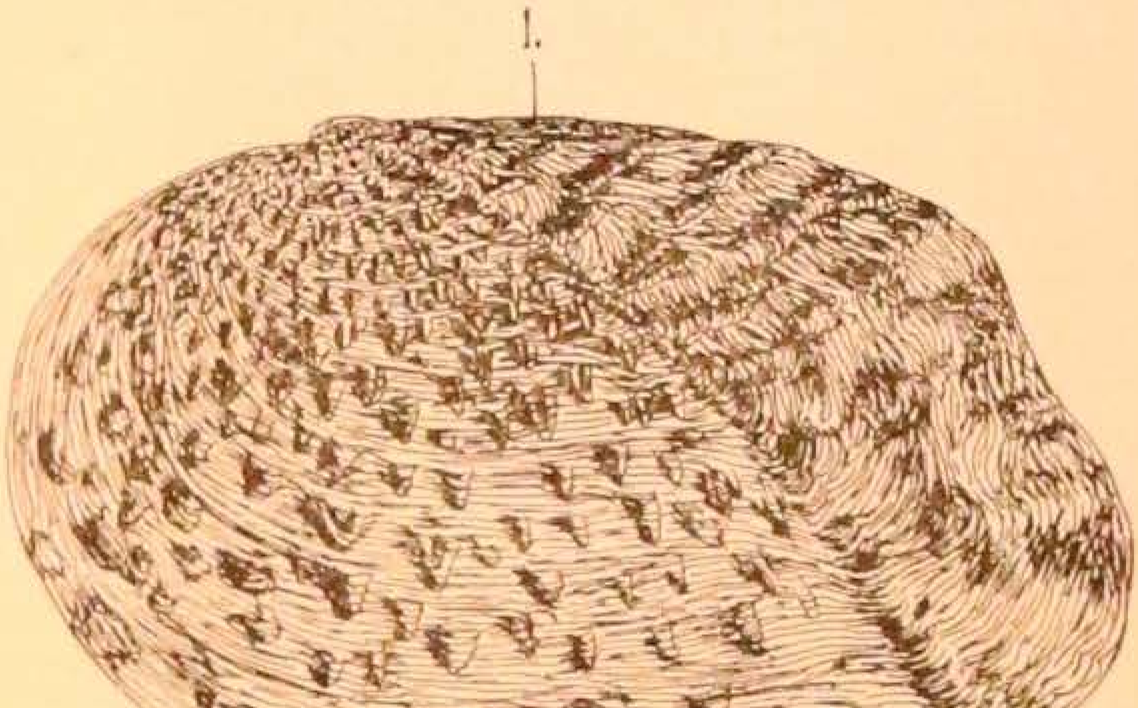

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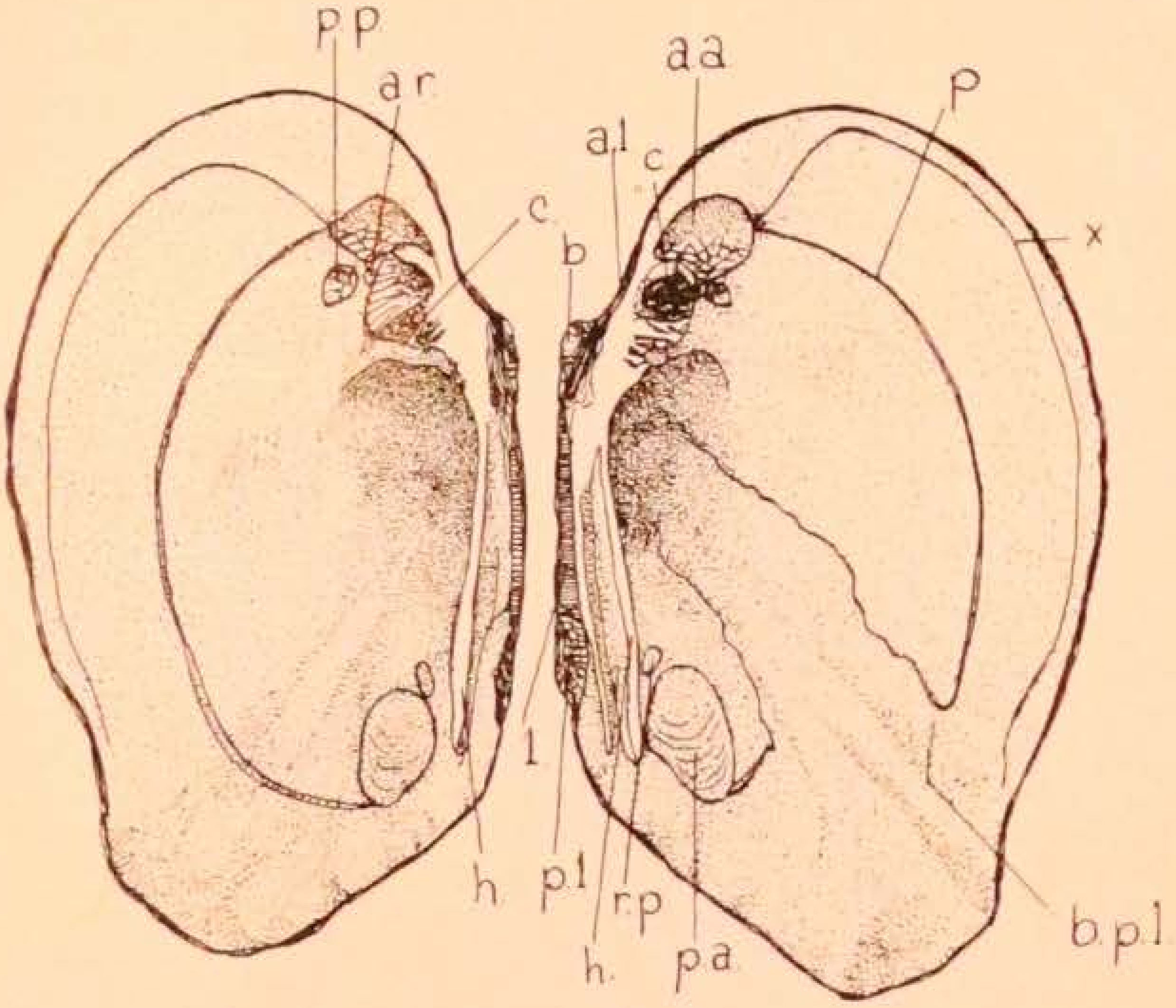
PLATE II

Key to figure 3. Interior of valves. *Tritogonia tuberculata*

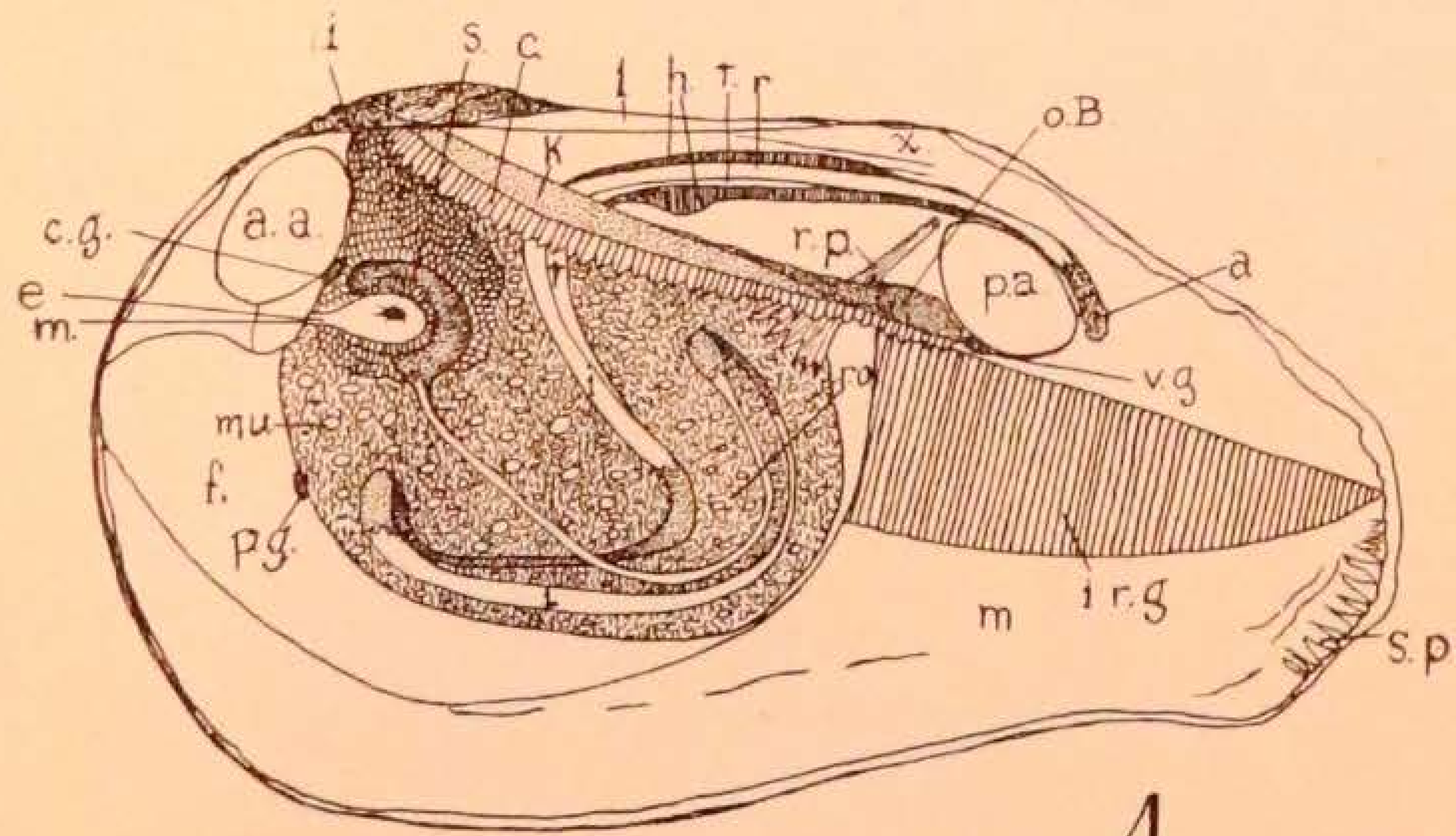
p. pallial line
p.p. protractor pedis scar
a.r. anterior retractor pedis scar
r.p. posterior retractor pedis scar
p.a. posterior adductor scar
a.a. anterior adductor scar
b.p.l. break in pallial line
x. groove probably representing peripheral artery of mantle
l. ligament
p.l. posterior lunule
a.l. anterior lunule
b. beak
c. cardinal teeth
h. hinge teeth

Key to figure 4. Conventionalized section through visceral mass in right valve

li. liver
a.a. anterior adductor
r.p. posterior retractor pedis
p.a. posterior adductor
s.p. siphonal papilla
h. heart
l. ligament
x. fold of the mantle above the hinge teeth
c.g. cerebral ganglion
p.g. pedal ganglion
v.g. visceral ganglion
K. Keber's organ
o.B. organ of Bojanus
r.o. reproductive organs
m. mouth
e. esophagus
s. stomach
i. intestine
t. typhlosole
r. rectum
a. anus
f. foot
i.r.g. inner right gill
m. mantle
c. cut edge of outer left gill
mu. transverse muscles of visceral mass


p.p.
a.r.
c.
b
a.l
c
a.a.
p
x
l
h.
p.l
r.p
h.
p.a
b.p.l

3


i
s.
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p.a.
a
v.g
mu
f.
p.g.
i.r.g
m
s.p

4

PLATE III

Key to figure 5. Internal structures shown in the right valve. Left valve and left fold of mantle removed

- a.a. anterior adductor muscle in section
- p.a. posterior adductor muscle in section
- p.p. protractor pedis
- r.p.a. anterior retractor pedis
- r.p.p. posterior retractor pedis
- s.b.c. superbranchial chamber
- e.s. exhalant siphon
- i.s. inhalant siphon
- v.m. visceral mass
- f. foot
- s.t. siphonal tentacle or papilla=fimbria
- l. ligament
- b. beak
- i.l.g. inner left gill
- o.l.g. outer left gill
- m. mantle
- a.l. anterior lunule

Key to figure 6. Detail of vertical section of a labial palp

- r. ridge
- g. groove
- e. epithelium
- b.m. basement membrane
- c.t. connective tissue
- c. cilia

Key to figure 7. Detail of vertical section of ventral furrow at junction of labial palps

- v.f. ventral furrow
- l.f. lateral furrows

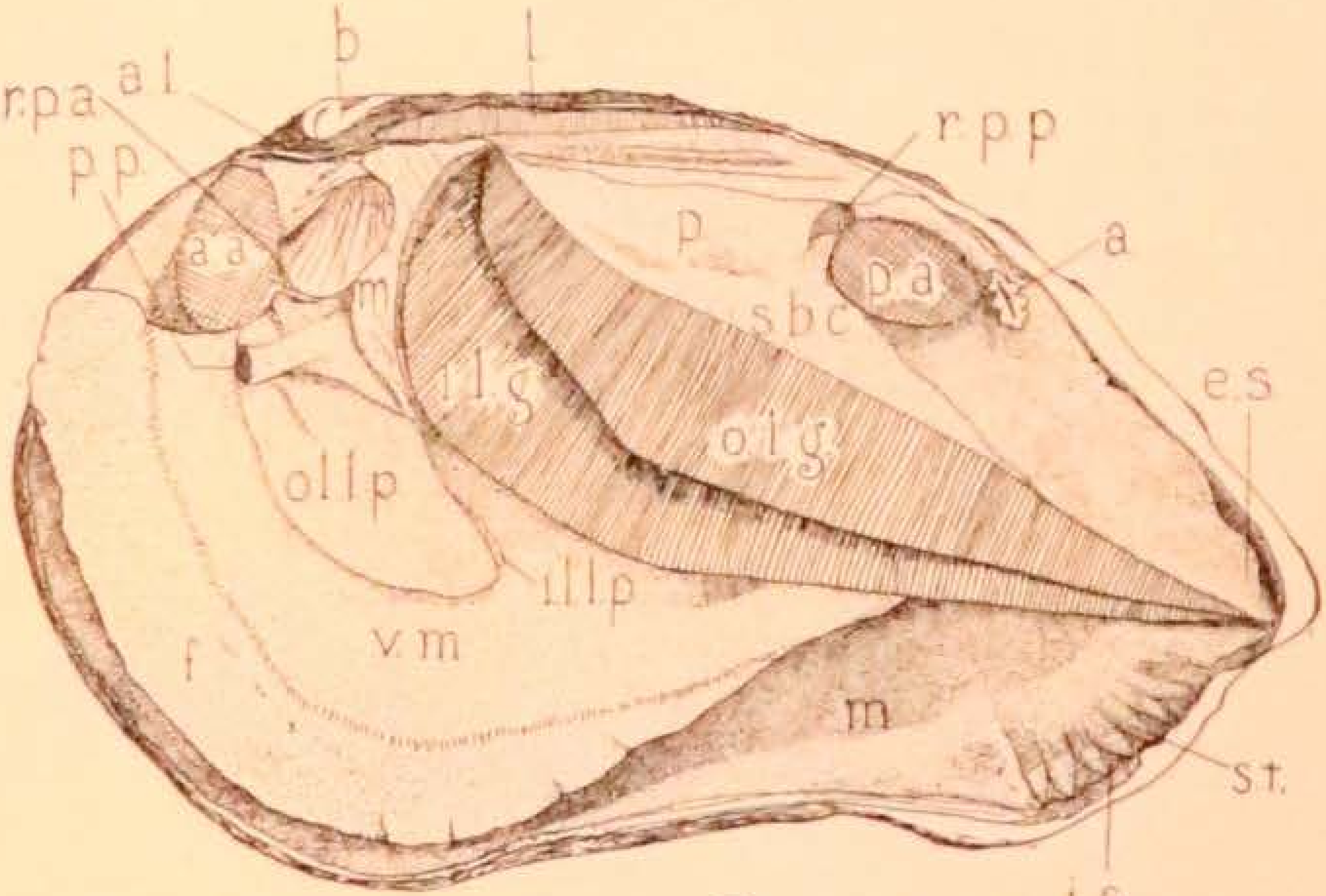
Key to figure 8. Detail of epithelium from ventral portion of dorsal furrow of labial palps

- b.m. basement membrane
- g. secreting goblet cell
- m. mucous cell
- c. cilia
- w. wandering cell

Key to figure 9. Detail of fragment of pedal ganglia

- n. nerve cells
- p. parasitic sporocysts

PLATE III



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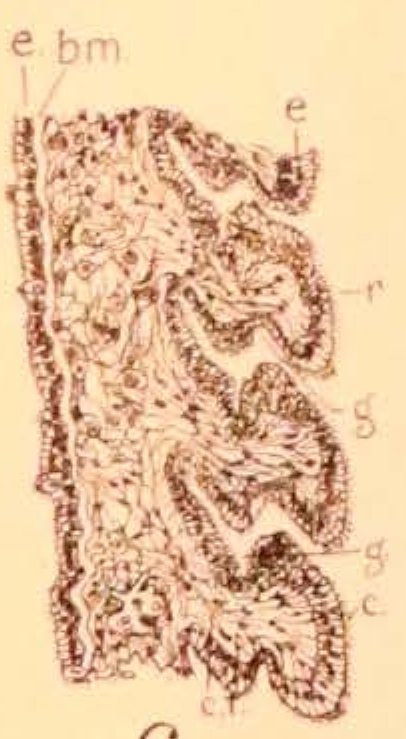

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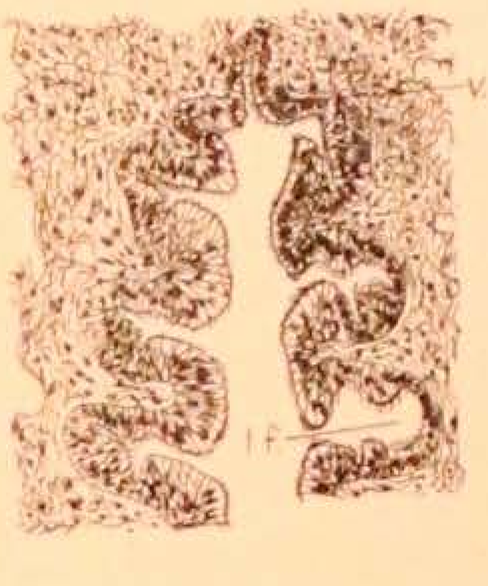

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PLATE IV

Key to figure 10. Vertical section through labial palps

d.f.	dorsal furrow
c.t.	connective tissue with cut ends of small bloodvessels
e.	epithelium
a.	labial palp artery
r.	ridge
g.	grooves
v.f.	ventral furrow
l.f.	lateral furrow

10

PLATE V

Key to figure 11. Free-hand transverse section through edge of mantle

- o.e. outer epithelium
- c.t. connective tissue layer
- m. muscles
- i.e. inner epithelium
- i.f. inner fold
- s.p. siphonal papilla
- m.f. middle fold
- o.f. outer fold
- p. periostracum
- c. masses of calcareous granules

Key to figure 12. Detail of inner lobe of mantle—10 micra thick

- m. mucous material

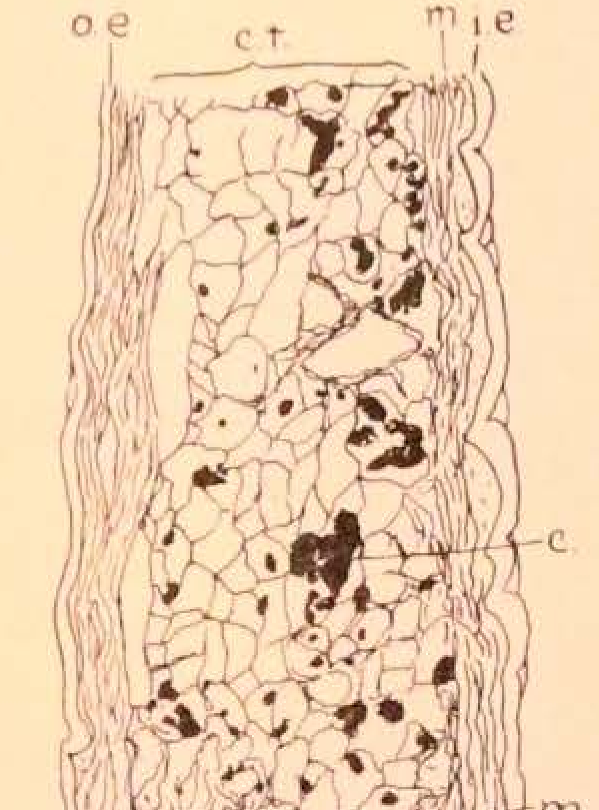
Key to figure 13. Detail of groove secreting periostracum—10 micra thick

- p. periostracum
- pi. pigment in epithelium
- o.f. outer fold
- m.f. middle fold

Key to figure 14. Detail of layers on outer side of mantle. Oil immersion

- e. epithelium
- b.m. basement membrane
- m. muscle cells
- w.c. wandering cells
- c.t. connective tissue
- t.m. transversely cut muscle cells

PLATE V



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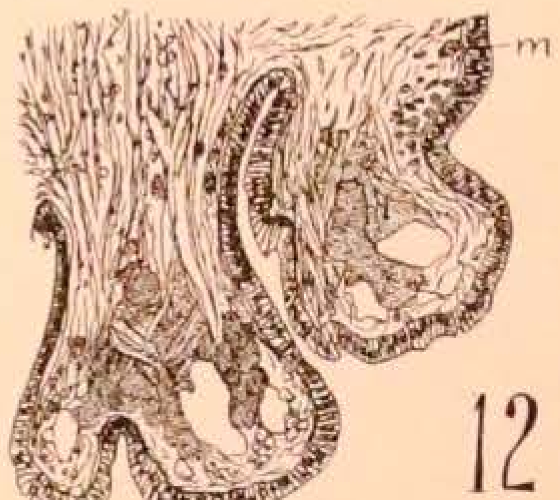

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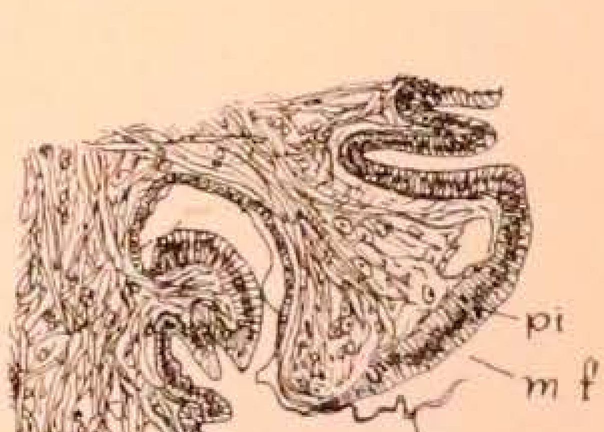

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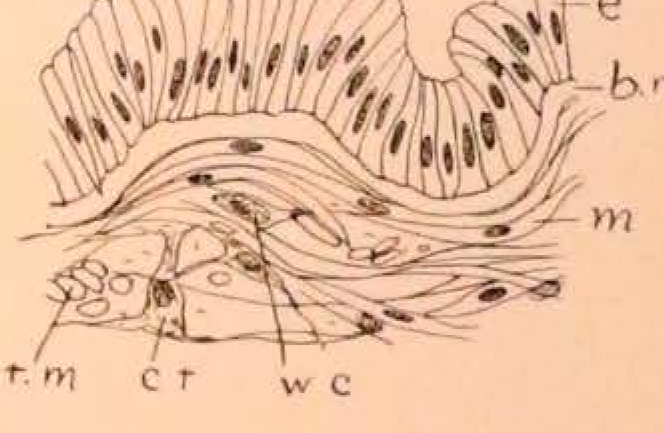

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PLATE VI

Key to figure 15. Cross-section through folds of the wall of the glandular portion of the organ of Bojanus

- l. leucocyte
- e. epithelium
- c. connective tissue

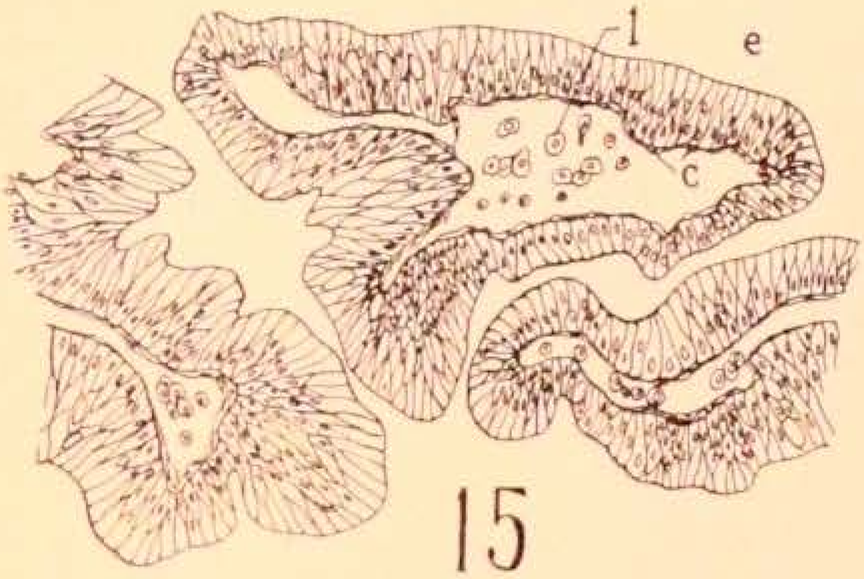
Key to figure 16. Epithelium of the ventral part of foot

- e. epithelium
- s. sub-epithelial mucous cells
- m. muscles
- c. connective tissue

Key to figure 17. Cross-section through dorsal portion of gills

- a.n. arterial net
- v.n. venous net
- c. connecting vessels between arterial and venous nets
- w.t. water tube
- i.l.j. interlamellar junction
- la. lamina of gill
- i.a. interlamellar artery
- os. ostium
- f. filament
- c. ciliated epithelium
- r. supporting rods
- m. mucous material

PLATE VI



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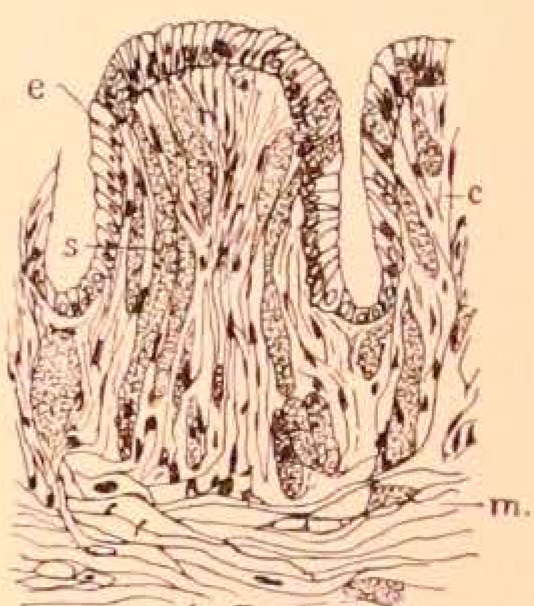

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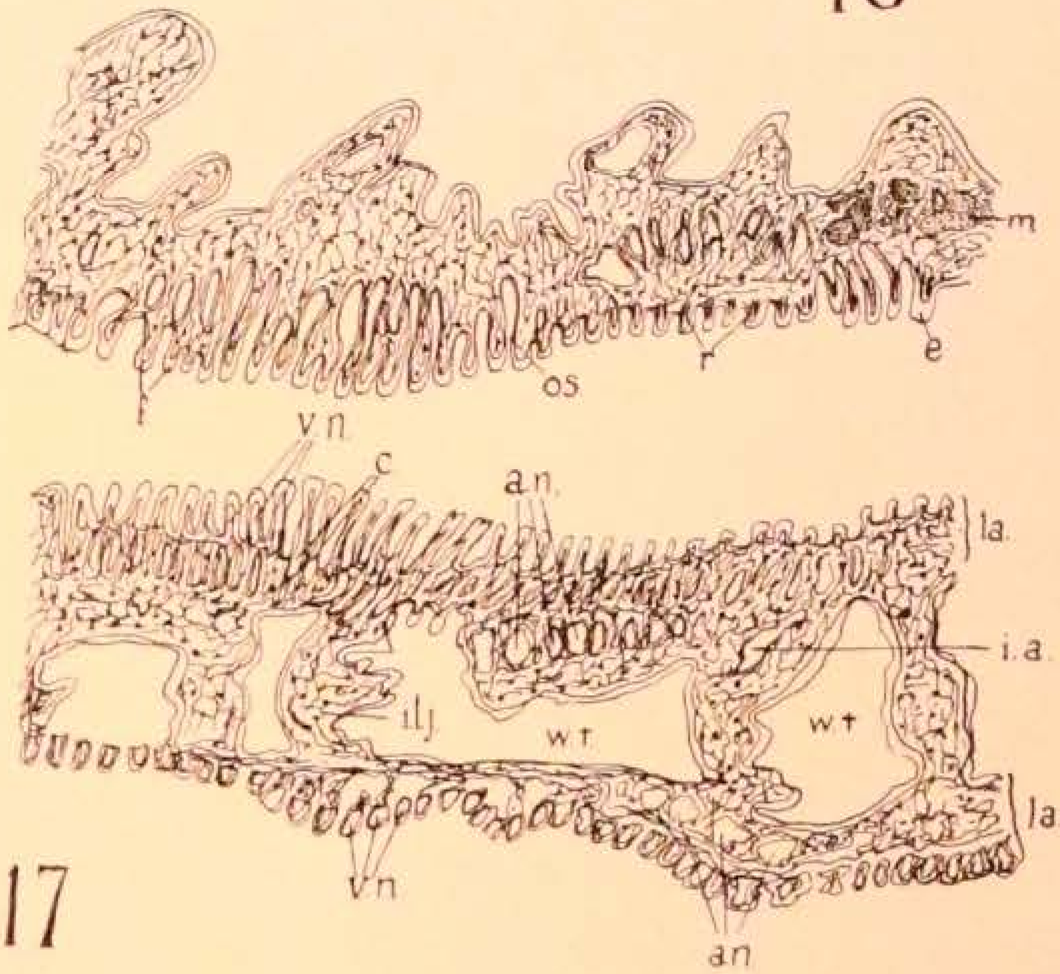

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PLATE VII

Key to figure 18. Cross-section through liver

- t. tubules
- d. duct

Key to figure 19. Detail of figure 18

- t. tubule
- d. lumen of duct
- e. ciliated epithelium of duct
- g. goblet cell

Key to figure 20. Cross-section of rectum in region of the heart

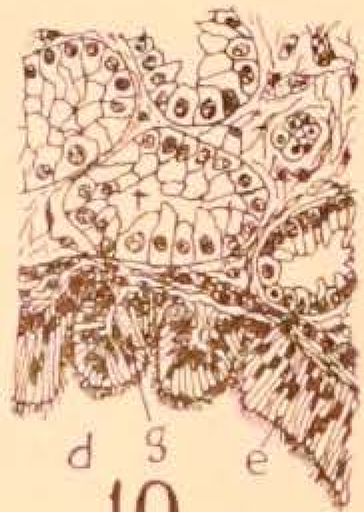
- t. typhlosole
- c. connective tissue
- e. ciliated epithelium
- r. lumen of rectum

Key to figure 21. Conventionalized cross-section through visceral mass

- n.c. nerve commissure
- o.B. cut ducts of glandular portion of organ of Bojanus
- i. intestine
- t. typhlosole
- r.o. reproductive organs
- t.m. transverse muscles of foot and visceral mass
- m. muscles of the foot
- e. folded epithelium and subepithelial mucous cells

PLATE VII

18



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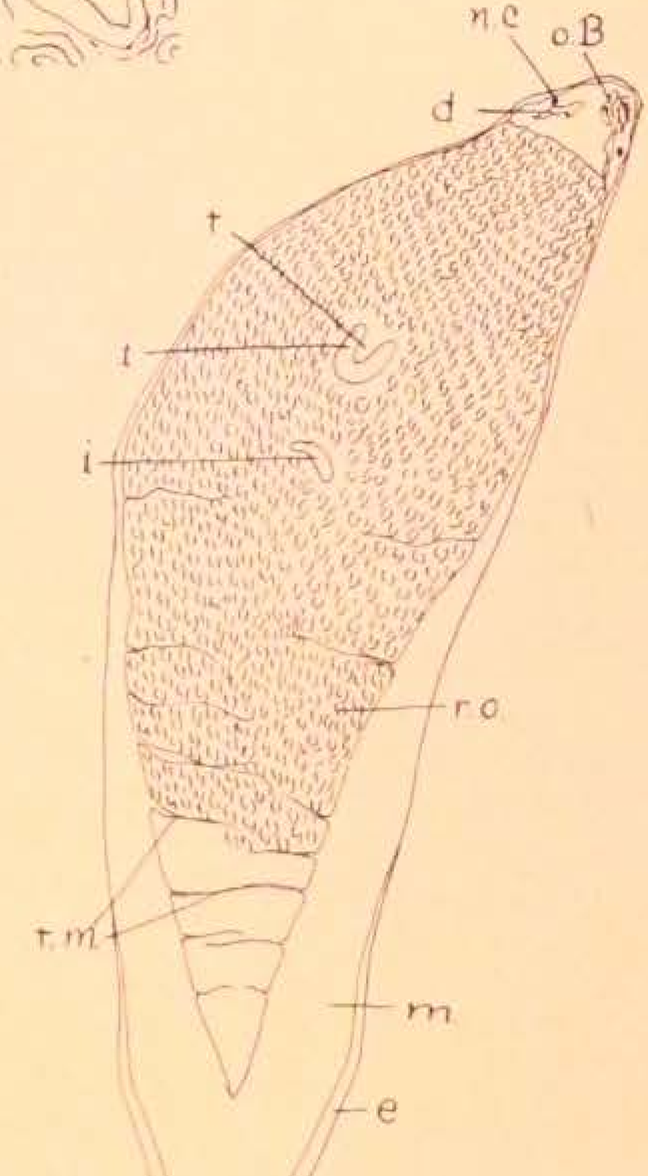

21

ECOLOGICAL STUDIES OF THE SHORT-NOSED GAR-PIKE (LEPIDOSTEUS PLATYSTOMUS)

George E. Potter

During the past four summers a study has been made upon the short-nosed gar-pike in the Okoboji Lakes, Dickinson County, Iowa. The work was carried on at the Lakeside Laboratory of the Graduate College, State University of Iowa.

There is a group of seven lakes in the vicinity: West Okoboji, Spirit Lake, East Okoboji, Upper Gar, Middle Gar, Lower Gar, and Center Lake. West Okoboji, where a major part of the work was done, has a length of five and forty-six one hundredths miles, a width of two and eighty-four one hundredths miles, an area of three thousand seven hundred eighty-eight acres, a mean depth of forty feet and a shore line of eighteen and two tenths miles.

In these waters are to be found several fresh water habitats. Some of these are:—(1) the deep water habitat including water from twenty to one hundred and thirty-two feet in depth, (2) the pond-weed or water-plant habitat, found in water from five to twenty feet in depth and (3) the shoal or shore habitat, extending from the shore out to where the water plants become abundant, the depth varying from a few inches to four or five feet. It is in the last two habitats that the short-nosed gar-pikes are most abundantly found in the summer, because it is here that they find their favorite food and resting place. These two above named habitats are particularly extensive in Miller's Bay and Emerson's Bay of West Okoboji and in upper Gar Lake. These areas are indicated by an X on the accompanying map of the region.

Observations were made on the gar-pikes by floating quietly over the water in a row-boat or from standing on the shore. Field glasses were used to good advantage in either case. Specimens were taken for the purpose of examining the stomach content and studying the sexual conditions by two methods; (a) with an ordinary drag-net or seine and (b) by shooting them with a rifle. Gar-pikes have a habit of basking at the surface of the water, in which situation a hunter may slip quite close in a boat, and, with a well aimed shot, kill the fish, or at least detain it until it can be taken into the boat with a dip-net. A number of the young were taken with the dip-net from the shore.

The gar-pike belongs to the order Holostei and it has been suggested by systematists that this order is in direct line between selachians and amphibians, the teleosts branching from it. The group is divided into several families all of which, except two, are extinct. The Amiidæ are represented by the Bow-fin (*Amia calva*) a fish with fusiform body, thin imbricated cycloid scales, and a cellular air-bladder. It is abundant in the waters of North America. The second family is the Lepidosteidæ (Gar-pikes) with an elongate body, both of the jaws greatly elongated to form a beak. The maxilla is divided into several segments, both jaws with sharp bony teeth, the tail nearly heterocercal, air-bladder cellular, eyes small, nostrils near the anterior end of the beak, scales rhombic, ganoid and articulated. There is one living genus *Lepidosteus*, whose representatives inhabit the waters of North and Central America. The three common species are; *L. platystomus* or short-nosed gar-pike usually smaller and having a somewhat shorter but broader beak than the following species, *L. osseus* or common long-nosed gar-pike, which has a very long beak (six or seven inches); these two are well distributed throughout the waters of the middle United States while the third, *L. tristœchus*, a much larger fish (eight to ten feet) is found in the water of Central America and the Southern United States.

FEEDING HABITS

The gar-pike is quite carnivorous in its food habits, a fact which has considerable bearing upon its status as related to other aquatic animals. The methods used in ascertaining the food habits of this fish have been, (1) to capture them alive, keep them in captivity, and feed them, noting the manner of taking and the different kinds of food that will be accepted; and (2) in other specimens dissect the stomachs and examine the contents as soon as fish are collected. The food of this form proved to be almost entirely animal matter. Occasional small bits of plant tissue were found in the stomachs but, since the amount was always very small and such occurrences rare, it is supposed that they were accidentally taken with other food.

The writer has previously published tables[1] of data on the food

[1] Iowa Academy of Science, Vol. XXX, 1923.

of this animal, so the discussion here will be of a more general nature. Other fish, such as perch (*Perca flavescens*), bluegill sunfish (*Lepomis pallidus*), common sunfish (*Eupomotis gibbosus*), several species of minnows and perhaps others, make up about two thirds of the food material as found in stomach examinations. The other one third was composed of crayfish bodies. In a number of cases there were parts of several such bodies and nothing else.

Stephen A. Forbes, in his paper "Food relations of fresh water fishes" mentions stomach examinations of six specimens in which he found only the bodies of other fish including, hickory shad, black bass and minnows. Forbes and Richardson in their "Fishes of Illinois" state that young gar-pikes will live very well upon mosquito larvæ alone. Mr. H. E. Richardson reports that a sixteen day old specimen had eaten several individuals of a small crustacean, *Scapholeberis mucronata*, nothing else. In another connection he says that the adults in the Illinois river have been seen swimming near the surface and breaking water at intervals to seize emerging gnats and may-flies.

During the warmer weather of the summer months the gar-pike is more active and seems to do most of its feeding in the morning hours, spending the later hours of the day basking in the sun at the surface of the water. The food is captured by grasping it in the toothed jaws. In case the food is another fish it is usually caught with the length of the body across the gar-pike's mouth, which necessitates manipulating it into position so the fish can be swallowed head foremost. The writer has kept live gar-pikes in captivity for long periods of time feeding them every four or five days upon dead sunfish or perch up to five or six inches in length or upon beef liver cut into pieces about one inch square which the animals swallowed whole. The fish have some difficulty in getting the dead objects from the ground to the mouth, but after a trial or two they give the object a quick push with their long jaws and seize it while it is up in the water. It is not uncommon for a gar-pike two feet long to swallow perch that are six inches in length or sunfish that are five inches long.

The food habits, it is seen, are not confined to just one or two species of other animals, but include several, some of which have quite diverse aquatic habits. The gar-pike then, as far as food habits are concerned, has not greatly limited its ecological range in the fresh waters.

GROUND

The ground or lake bottom over which the gars are found varies a great deal. Since they are not primarily ground feeders it does not affect them greatly, except as it influences the habits of the animals upon which they prey. The perch, sunfish and bass generally occur in a more or less vegetated area of mucky or sandy loam bottom. Their food, which is insect larvæ, small crustaceans, plants and some small fish, is found here.

The gar-pike itself eats crayfish and hence it is often seen along sandy or gravelly shores, where these animals abound. The ground seems to be a rather indirect factor in the environment of this fish.

ASSOCIATIONS

All living animals have certain relations with other animals and with plants. Naturally the animal associates of the gar-pike are other aquatic animals, with somewhat similar habits. Many of these are made use of as food, others just seem to happen to be together, while still others have nearly the same food habits as the gar, and compete more or less with it.

These associated animals are so divided and their status given in the following tables.

I. Used by the Gar-pike as Food

Yellow perch	*Perca flavescens*	Abundant
Pumpkin-seed	*Eupomotis gibbosus*	Abundant
Bluegill	*Lepomis pallidus*	Abundant
Green sunfish	*Lepomis cyanellus*	Rather common
Minnows	Cyprinidæ	Abundant
Black bass[2]	*Micropterus salmoides*	Common
Hickory shad[2]	*Dorosoma cepedianum*	Rare
Crayfish	*Cambarus virilis*	Abundant
Fly larvæ[3]	Diptera	
Damsel fly larvæ[3]	Odonata	

II. Accidental Associates

German carp	*Cyprinus carpio*	Abundant
Common sucker	*Catostomus commersoni*	Rare
Bullhead	*Ameiurus nebulosus*	Common
Leopard Frog	*Rana pipiens*	Common
Bell's turtle	*Chrysemys m. belli*	Abundant
Snapping turtle	*Chelydra serpentina*	Common

2 Forbes in "Food Relations of Fresh Water Fishes."

3 Pearse in "The Food of the Shore Fishes of Certain Wisconsin Lakes."

III. Those of Similar Food Habits

Black bass	*Micropterus salmoides*	Common
Rock bass	*Ambloplites rupestris*	Rare
Bullhead	*Ameiurus nebulosus*	Common
Wall-eyed pike	*Stizostedion vitreum*	Rare
Common pike	*Esox lucius*	Rare

In the first table it is noticed that the perch, sunfish, bluegill and crayfish are abundant in the regions where the gar-pike are found. The rule is quite consistent that if a gar is in a community at least some of the others mentioned will be there also. The group of accidental associates may be brought into the same society by their food habits, for protection, or to reproduce. All of these activities may be somewhat different from the corresponding habits of the gar-pike. For instance the carp is a ground feeder, but in an area where there are water plants, there is much food for it. Other species come to these regions because the plants afford protection for both adult and young. There is a number of other animals whose food consists of the same material as that of the fish listed. The search for their favorite food therefore brings them into association with the gar-pike.

PLANT ASSOCIATIONS

In the portion of the lakes where the gar-pikes congregate and are nearly always to be found, certain water plants usually occur. The most important of these is *Ceratophyllum demersum*, a long slender-stemmed plant, often many feet from one extremity to the other. This weed grows to form a very dense mass, much of which is at the surface, where it spreads out forming an even, green mat. Among the *Ceratophyllum* in the shallower water is often found *Myriophyllum*, a somewhat similar plant. Still another plant which occurs in the habitat of the gar, is *Potamogeton* of several species. On the bottom in some places there is a great deal of *Chara*. Numerous kinds of algæ are found throughout the water.

The dense growth of plants affords food and protection for many fish, small crustaceans, molluscs and larvæ of insects. Therefore they will be attracted here. The gars come here in search of these animals for food, for the direct protection the plants offer, and for a suitable place to breed.

TOLERANCE TO ENVIRONMENTAL CONDITIONS

This animal is able to tolerate many severe conditions which are fatal to most other species of fish in a very short time. The writer once found a gar-pike trapped in an old fish cage. Either the animal was able to get into the cage at a time when the water level was higher (as it had been a month before) and was unable to get out, or someone had placed the animal there. At any rate it was held captive and the water had lowered until most of its back projected out of the small amount of very muddy water in the puddle. There was a small connection of water between that in the cage and the main lake. The oxygen supply of the little puddle must have been nearly negligible but the fish was able to survive without much apparent discomfort.

Following this incident, some experiments were made in view of getting a definite idea of the fish's tolerance in this respect. A live gar-pike was placed in a vessel containing five gallons of water that tested 8 cc. of oxygen per liter (Winkler method). The vessel was covered with screen, but with some space between the screen and the water. At the end of twenty-four hours the water was again tested for oxygen and this time the test was 1.9 cc. per liter. The fish was still alive and apparently not suffering in the least. At the end of twenty days, after the water had become extremely foul, the fish died. The water was tested for oxygen several times during this period and the amount present always corresponded very closely to the amount found at the end of the first twenty-four hours. The test has been repeated a number of times and the results coincide. It was noticed that almost continually during the experiment, the fish would come to the surface at intervals of several minutes and gasp in air. This same action has been noticed by the writer and others when the gar-pike is in natural waters where the oxygen content is low. From this it seems quite evident that the gar-pike has other means of respiration besides the gills. It has been stated by others that this animal uses the air-bladder as a respiratory organ, but the writer, not having completed experiments to determine which organ does the respiring in this case, is not ready as yet to make a statement. The bullhead (*Ameiurus nebulosus*) and bow-fin (*Amia calva*) are probably its closest rivals in respect to tolerance of low oxygen supply, while perch and sunfish will die in a few minutes under the same conditions.

The gar-pike has great endurance in respect to rough handling when compared to many other fish, such as the perch, sunfish, bass, or minnows, many of which will succumb from simply being dragged ashore in a net. The heavy armor of scales offers very good protection from injuries by physical contact.

This ability to endure severe conditions along with the gar-pike's predaceous habits, strong swimming powers and its natural protective coat of armor-like ganoid scales have probably been responsible for its long, successful existence. These factors, no doubt, also have a bearing upon the abundant numbers of these fish to be found in some localities.

ECONOMIC IMPORTANCE

The gar-pike is a branded fish and has a wide-spread reputation for being a worthless nuisance. Since it is predaceous and a voracious feeder, the gar is very destructive to other fish. In Lake Okoboji its principle food is perch and sunfish and it is reported that black bass have been found in its stomach. These fish are all used as food and game by man, so he begrudges the gar-pike the large number that it captures.

The fact that the gar-pike feeds upon crayfish, minnows and a few insect larvæ is a second charge against it. Since the rock bass, black bass, pickerel, and others which are valuable food fish make use of these for food, the large amount of this sort of food consumed by the gar-pike only subtracts from the supply for these more valuable species. Many nets and other fishing tackle are destroyed each year by these strong fish. It is reported by the U. S. Bureau of Fisheries that in Carolina the nets of the commercial shad fisheries often become loaded with gars, nearly to the exclusion of the marketable fish. At the same time the nets are frequently torn by the active struggle of the gars.

The fleshy part of the upper sides or "loin" of this fish has been used for food by Indians, but usually white people have not been able to rid it of the strong fishy taste and odor. However after being soaked in brine over night and well baked the meat is fairly palatable. It is reported that in the Mississippi river the gars serve as host for glochidia of the Yellow Sand Shell Clam (*Lampsilis anodontoides*), an important button producer. Little else can be said in favor of the fish. It is the enemy of most other fishes at some stage of their lives and with its strong swimming powers, adaptability and other natural protection, it is quite safe from other aquatic animals and conditions. As yet no satisfactory way has been devised for clearing our waters of them, if that is desirable. However it has become customary among fishermen upon catching them, to either throw them out on the shore to die or to break their heads from their bodies.

LIFE HISTORY

As has been shown, this fish has a rather characteristic life career. It is endowed with means for leading a very predaceous life, and with ability to protect itself from enemies, as well as having a fairly rapid rate of reproduction, so it is able to perpetuate its kind quite successfully. The seasonal cycle is about as follows. During the summer, June, July, and August, many of these animals come into the shallow bays, Little Miller's and Little Emerson's in West Okoboji, where they feed upon smaller fish and spend a great deal of time basking in the sun on warm days. Then about the end of August they begin to be less abundant in these shallow bays, making their way to the deeper water for the winter. Fishermen of this region say that they have seen gars through holes in the ice. They will move along quite near the ice, passing across the open hole, apparently not afraid of a man who is moving about. Their movements under the ice seem quite aimless. The low temperature, slowing up the metabolism, is more than likely responsible for this semi-coma, since the writer has kept live specimens through the winter months in tanks at a temperature of seventy degrees F., with no such results.

The time of spawning is quite irregular with the gar. The weather conditions seem to cause some general variations, that is, if the temperature remains low until late in the spring, the general spawning season for the animal will be a little later. There is much variation in the time of spawning among individuals, some spawning as late as July. Several were seen apparently spawning on May twentieth, in the south end of Lower Gar Lake. These were the first to be observed spawning that season (1923).

The water in the lower end of Lower Gar Lake is quite shallow, in fact that part of the lake is no more than a slough. It is here, in this shallow water where there are some weeds to which the eggs may attach, that the spawning occurs. Sometimes one animal, supposed to be a female, is attended by two or more others, presumed to be males, but occasionally they swim in pairs. There is a great deal of rubbing back and forth along the sides of the female as they all move repeatedly over the same ground. Suddenly the female slaps her tail out of the water with a splash and the fish are gone from the spot.

The eggs are deposited in small masses, held together by a clear gelatinous substance, which attaches to the weeds or even to the lake bottom. The individual eggs are about the size of buck-shot, or 3.5 mm. in diameter, and are dirty-yellowish in color. Their appearance is different, perhaps, from that of any other egg. Under favorable conditions Mr. R. E. Richardson has found that the eggs will hatch in eight days. The young fish are very slender and carry a yolk sac attached to their ventral side. They remain in this condition about seven days when the yolk sac is entirely absorbed. This period when the young gar is carrying the large yolk sac is the most helpless part of its whole life. As soon as the sac is absorbed the fish is a very slender, active animal. It is slaty gray in color at this time and marked with a broad lateral line of black.

During this time the principal food is probably Entomostraca and mosquito larvæ. But very soon they start their predaceous habit of preying on other fish. Forbes and Richardson make mention of a specimen an inch and a quarter long which had taken a minute fish, and another two inches long and only an eighth of an inch in depth had filled itself with no less than sixteen very young minnows. These young gars stay in the shallow water, and at Okoboji in an artificial canal among the water plants, until fall when they go to deeper water with the adults. About fifteen of the fish, varying in length from two and one half to five inches, were taken in the above mentioned canal in August by dipping them up in a net from the shore. The fry and fingerling are very seldom seen because of their slender build, grayish color, shy habits and quick actions. Those which have been found were solitary near the shore, usually among plants and over a muddy bottom. In this way the young animals are afforded very effective protection. They attain a length of four to six inches the first summer, so as a rule the smallest gars seen are at least this large. Their growth is slightly slower the second season and the animals become bolder.

The specimens seen, which where supposed to be spawning, were all at least fifteen inches or more in length which is larger than the second year animal, so it is likely that reproduction does not begin until after the second year. They are very prolific, the mature ovaries of a large female often weighing more than a pound. Dr. Evermann reports that a female weighing nine pounds, contained, by actual count, 36,460 eggs. It is, then, evident that there is opportunity for rapid increase in their numbers.

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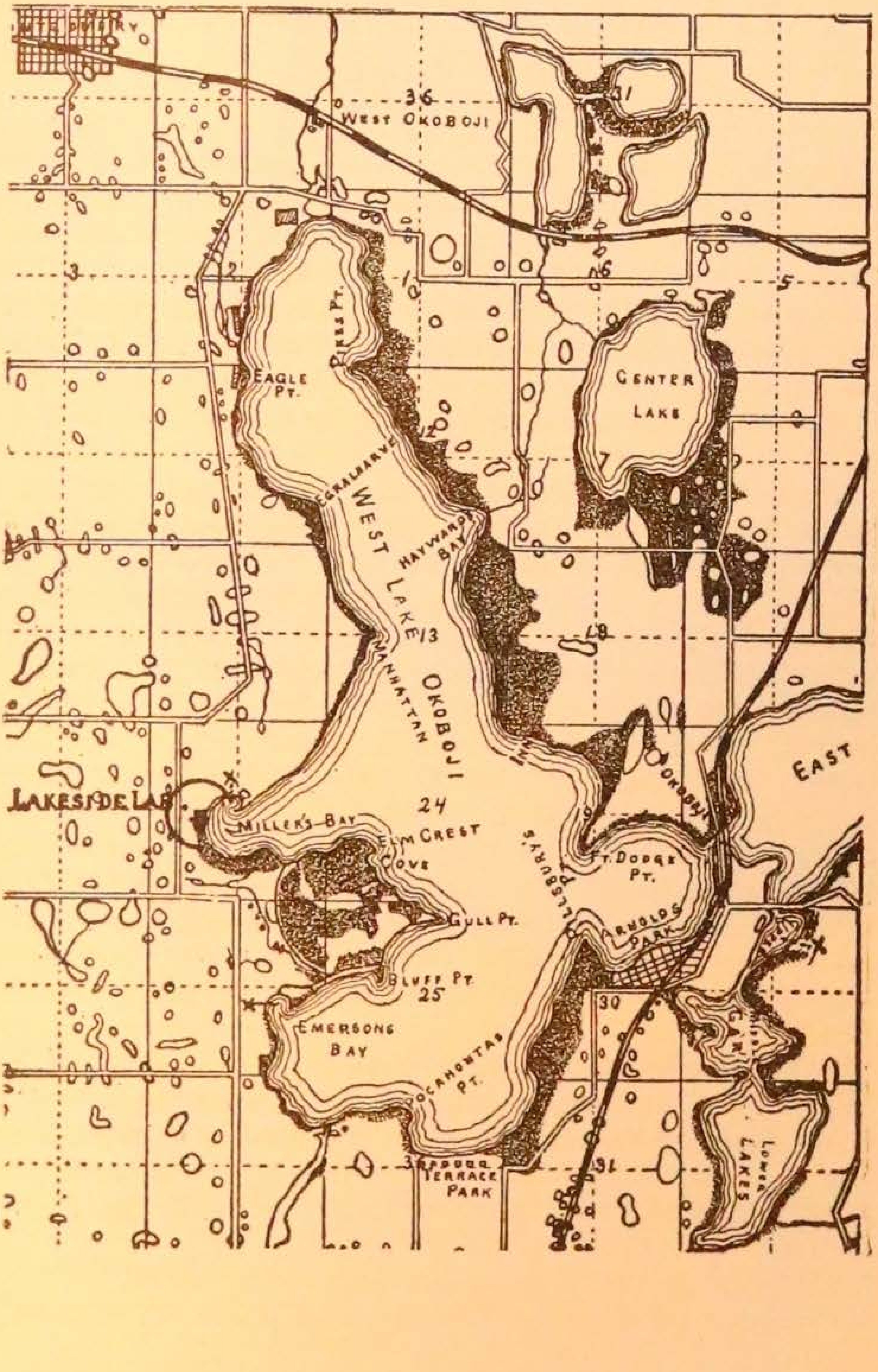
West Okoboji
36
31
Eagle Pt.
Center Lake
West Lake Okoboji
Hayward Bay
Manhattan
Lakeside Lab.
24
Miller's Bay
Elm Crest Cove
Gull Pt.
Ft. Dodge Pt.
Arnolds Park
Bluff Pt.
25
Emersons Bay
Terrace Park
East
Lower Lakes
30

WATER MITES OF THE OKOBOJI REGION

RUTH MARSHALL
Rockford College

During the summer of 1924 the author spent some weeks at the Lakeside Laboratory of the University of Iowa, near Milford, in the Okoboji lake region of the northwestern part of the state. Through the courtesy of Dr. Frank A. Stromsten, Director of the Laboratory, facilities for collecting and studying the water mites were provided; the author wishes to acknowledge here the assistance which was received in the work. This paper is a contribution to the work of the Laboratory in securing data on the life of the lakes.

The Okoboji region is especially favorable for collecting hydracarina, since it abounds in shallow lakes, ponds and sloughs which support an abundant aquatic vegetation. The conditions are typical of a recently glaciated region of the upper Mississippi basin. Collections were made in July and August. Most of the material was secured from West Okoboji, the largest of the lakes, and especially in and near Miller's Bay, where the Laboratory is located. Other lakes visited which yielded material were East Okoboji, Upper Gar, Spirit, Hottes, Little Spirit, Center, Robinson, and Sunken Lakes, Milford Creek at the dam, the canals and several of the sloughs in the region, and Loon Lake just over the Minnesota boundary line. A little material was secured in Clear Lake and in small pools near Charles City, some distance east of the Okoboji lakes. No mites were found in Welch, Drummond, Middle and Lower Gar lakes, nor in several of the muddy bordered sloughs visited.

In addition to the material secured by the author by the use of a modified Birge collecting net, several hundred parasitic mites of the genus *Unionicola* were added to the collection through the courtesy of Dr. H. M. Kelly, of Cornell College, who found them in the course of his investigations on the trematode parasites of the fresh water mussels of the lakes.

Altogether, several hundred individuals were secured; of these, the parasitic Unionicolæ and one species of *Piona* (*P. reighardi*), claimed the largest number. Fifteen genera were represented and thirty-seven species and varieties, of which eight were Arrhenuri. Five of the species appear to be new and are here figured and described. In this connection it must be pointed out that many of the ninety or more recognized genera of the hydracarinæ have never been thoroughly studied in this country, and there are as yet no published lists of the North American species of many of the genera. Consequently, the new species published here for the first time are, quite probably, not rare nor peculiar to the Okoboji region but only now recorded. In support of this view, it may be mentioned that no new species were found for the genera *Arrhenurus* and *Piona*, large genera which have been studied intensively. It is not assumed, of course, that the list of the species given here is at all complete.

The order in which the genera are arranged is one of convenience only; the larger and better known genera are given first, while the representatives of the "red mites" are recorded last.

Genus Arrhenurus

The Arrhenuri, the largest genus of the water mites are always abundantly represented in waters like those of the Okoboji group. They were found in all the lakes except Center. Eight species were found, with more than one hundred and sixty individuals, besides several unidentified females and nymphs. Of these individuals, over half belong to three species of the "long tailed" forms (Subgenus *Megaluracarus*), *A. marshalli* Pier., *A. manubriator* Mar., and *A. megalurus* Mar. *Arrhenurus americanus* Mar. was also well represented; this species, with *A. marshalli*, the two American species of the genus most commonly found, claimed also the largest numbers here. The rarer species were *A. laticaudatus* Mar. (four individuals), *A. lyriger* Mar. (five), both found in West Okoboji; *A. laticornis* Mar. (two) in Upper Gar, and *A. trifoliatus* Mar. (one) in a small pool at the State Fish Hatchery, near Spirit Lake.

Genus Piona

This genus was the most widely distributed, as is to be expected in a region like Okoboji; several hundred individuals were found, as they were present in nearly every collection made. Five species were identified, by far the most abundant being *P. reighardi* (Wol.). This species, perhaps the most common American water mite, was found, both sexes and nymphs, to the number of several hundred. They were especially abundant in Loon Lake, Upper Gar and in some of the sloughs; and almost the entire catch from Robinson Lake consisted of mites of this species. *Piona pugilis* (Wol.) was found in Upper Gar, seven individuals; *P. inconstans* (Wol.), in Miller's Bay; *P. spinulosa* (Wol.), in Spirit Lake and Clear Lake; *P. rotunda* (Kram.), in Upper Gar. The last three species were each represented by one individual only.

Genus Limnesia

Over one hundred individuals of this common genus were found in the collecting grounds. Four species were identified, by far the largest being *Limnesia histrionica* (Herm.) ; this common and widely distributed species was especially abundant in Upper Gar and Center Lakes. The closely related form, *L. wolcotti* Piers., a variety of *L. histrionica*, was likewise found in several places. *Limnesia americana* Piers. was found (one female) in Clear Lake; and *L. paucispina* Wol. in Miller's Bay.

Genus Unionicola

The genus is represented by four species, three being parasites in clams. The free form is the cosmopolitan species, *Unionicola crassipes* (Müll.) ; this was found only in Miller's Bay, but nearly fifty individuals were secured, most of them in the deeper water outside of the bar.

The parasitic species were found by Dr. H. M. Kelly, who kindly made the identifications of the fresh water mussels in which they occurred. *Unionicola abnormipes* (Wol.) was found to the number of several hundred in the examination of some three hundred clams, *Lampsilis luteolus*, collected in West Okoboji and Spirit Lakes, at several stations. *Unionicola ypsilophora* var. *haldermani* (Piers.), with several hundred individuals in all, was found in about fifty *Anodonta grandis* from Spirit Lake; and *U. intermedia* var. *wolcotti* (Piers.), about twenty-five individuals, was found in one clam (probably *Lampsilis luteolus*), taken in the Little Sioux River by Mr. Brenkleman. The infection of these clams by the mites was almost one hundred per cent; the largest number found in one individual was one hundred and eighty-six.

Genus Lebertia

The Okoboji region is not favorable for mites of this large genus which are more abundant in deeper and cooler waters. But two individuals were found; these proved to be *Lebertia porosa* Thor, a cosmopolitan species. They were collected in Miller's Bay, outside of the bar.

Genus Frontipoda

One individual of the common species, *Frontipoda americana* Mar., was found in Loon Lake, Minnesota.

Genus Oxus

Oxus intermedius new species

Plate I, figs. 1-3

Three mites of this genus were found in a brief dredging in the border of Loon Lake, a shallow pond near Spirit Lake. They appear to belong to a new species.

The margins of the epimeral shield come barely into view on the dorsal surface; the posterior border has a deep U-shaped bay in which lies the genital area. The genital plates do not project beyond the bay, however, as is usual in *Oxus*. It is assumed, because of the deep set position of the genital plates, that the specimens are males. These plates are elongated and bear several very fine hairs each; the three acetabula usually found here could not be made out. The surface of the epimeral shield is closely beset with very fine points; the anterior part is pinkish in color, the rest of it greenish. The dorsal side of the body shows dark blotches. The palpi are rather small; the legs are greenish blue, the fourth ending in the usual long saber-like point instead of claws. The largest of the three individuals found measured 1.1 mm. in length and 0.6 mm. in the widest part; the two smaller were 0.9 mm. long and 0.6 mm. wide. In the latter, presumably somewhat younger individuals, the ventral shield was relatively a little larger than in the largest individual, from which the drawings were made.

Genus Neumania

Pl. II, figs. 10-12

Six species of the genus are here represented, one of which is new. *Neumania tenuipalpis* Mar. was the most abundant, being found in West and East Okoboji, Upper Gar and Loon Lakes and at the dam in Milford Creek. Three of the eighteen individuals found were females. As this sex has not been known before, a figure of the genital area is given (fig. 10). The living animals of both sexes show two wedge-shaped areas on the dorsal side which have very dark brown dots on a yellowish background, while a pale yellowish blotch lies anterior to them. The eyes are red. The body is covered with fine lines.

The new species, to which the name *N. okobojica* has been given, represented by one female individual only, was found in Upper Gar Lake.

Neumania okobojica new species

It is a large mite, 1.45 mm. long and 1.2 mm. wide, oval, dull greenish in color, with blue plates and legs and a heavy integument. The epimera are of the usual form and size, but the underlying braces from the first pair cannot be made out in a surface view. The palpi are very small but stout. The genital area of the female is close to the epimera and is very distinctive, since the plates of either side bearing the acetabula are separated, as shown in the figure (fig. 11).

The other species of the genus which were found were *N. punctata* Mar. (at the Narrows and in the "Little Canal"), three males; *N. ovata* Mar. (one, "Little Canal"), *N. semicircularis* Mar. (one each in Miller's Bay and Emerson Bay); *N. brevibranchiata* Mar. (two males, in Upper Gar).

Genus Hygrobates

The genus is characteristically a northern one; it is reported as common in northern Europe, and one species has been found by the author in large numbers in Alaska. But one individual was found in the Okoboji collections; this was a newly emerged male found in Miller's Bay outside of the bar. It appears to represent a new species, not hitherto described but already studied by the author.

Hygrobates ruber new species
Plate I, figs. 5-7

The new species is seen to resemble *H. calliger* Piers, differing from the European form in several details, especially in the genital plates. The figure given of the ventral plates of a mature female (fig. 5) was drawn from material collected by Professor F. C. Baker in Lake Winnebago, Wisconsin, and kindly turned over to the author. The epimeral plates are not large; they lie close together and the genital area is not far removed from them. The palpi are of the characteristic size and shape, with a well developed spiny peg on the second joint. The body in both sexes measures about 0.9 mm. The dorsal side of the body is brownish with a red streak on it; this latter character has suggested the specific name, *H. ruber*.

Genus Koenikea

This genus is represented here by the fairly common species, *Koenikea concava* Wol., the only species so far recorded for this continent. Eight individuals were found, taken from Miller's Bay, Upper Gar, the Narrows and Center Lake.

Genus Xystonatus

Of *Xystonatus asper* Wol., one individual was found in each of Upper Hottes and Clear Lakes. It is the only species of the genus recorded for North America.

Genus Hydryphantes

Adults and nymphs to the number of eighteen, found in four of the lakes (Hottes, Robinson, Sunken and Spirit), furnish the material for the formation of a new species of this genus.

Hydryphantes tenuabilis new species
Plate II, fig. 9; Plate III, figs. 16-18

The dorsal plate bearing the median eye is here reduced to an anterior bar with two divergent limbs, the posterior divided ends of which are somewhat variable in shape, as reported also in other species, and only faintly outlined. In the form of this plate, a character important in distinguishing the species of the genus, the new species resembles *H. ramosus* described by Daday from Paraguay. The body is ovate, bright deep red in color, and the largest specimen is 1.05 mm. long. The surface is thickly beset with fine rounded elevations. The ventral plates are close together, a little farther removed in younger individuals; all bear short bristles or hairs. The genital area is large, in the center of the body; each lateral plate bears three acetabula of about equal size. The genital plates of the nymph have two acetabula each. The legs are short, and the last three bear swimming hairs.

Genus Diplodontus

One species of this large genus was found; it is a common species, although here described for the first time, and given a name, *D. americanus*. In the Okoboji region it was found in Upper Gar, at the Narrows, and in Spirit, Sunken and Loon Lakes, twenty-eight individuals being secured. Of these, several were nymphs, and a few were newly emerged adults, all taken in late July and early August. The bodies of the females were filled with large globular eggs.

Diplodontus americanus new species
Pl. I, fig. 4; Pl. II, fig. 8; Pl. III, figs. 13-15

The body is almost circular in outline, orange red, with a large dark scalloped area on the dorsal side, the same coloring as in *D. despiciens* (Müll.), a very common and widely distributed species in the Old World and reported also for the Americas. Although the two species are otherwise very similar, *D. americanus* has a different form of genital plates, and these are closer in toward the last epimera and also broader posteriorly. In these particulars it more closely resembles *D. peregrinus* Koen., found in Brazil. In the palps, the projection of the fourth joint is a little smaller than the fifth joint with which it forms the claw. The epimeral plates are typical of the genus and bear many hairs. All of the ventral plates are close together in the very young adults. In the nymph, the genital area has four large acetabula. Newly emerged individuals measure 0.75 mm. in length; old adults were found from 1.3 to 1.75 mm. In other collections by the author they have been found as large as two millimeters.

Genus Eylais

Only one individual of this large genus of the "red mites" was secured. This was found at the dam, Milford Creek. Its identification is uncertain; it does not seem to conform to any of the few species of the genus as yet described for North America. Since determination of the species depends largely on details of the small dorsal eye plate, a character known to have considerable range of variation, it does not seem wise to record a species from the examination of only one specimen.

Genus Hydrachna

It is surprising to find that this large and common genus was not represented in the collections from the Okoboji waters. One individual, a young one, was found in Clear Lake, but it was not identified. Doubtless more systematic collecting at other stations would have yielded more material.

Corrections

In the paper, "Water mites of Alaska and the Canadian Northwest" (Trans. A.M.S., XLIII, 4, 1924), two regrettable errors occur, to which the attention of the author has been called in private correspondence. The specific name, *octoporus* (p. 238), being preoccupied, that of the new species will be changed to *Hygrobates neoöctoporus*. The new species *longiseta* (p. 243) given to *Piona* should be *Neumania longiseta*.

List of the Species

1. *Eylais* sp.
2. *Hydryphantes tenuabilis* new species
3. *Diplodontus americanus* new species
4. *Hydrachna* sp.
5. *Limnesia histrionica* (Herm.)
6. *Limnesia histrionica* var. *wolcotti* Piers.
7. *Limnesia americana* Piers.
8. *Limnesia paucispina* Wol.

9. *Lebertia porosa* Thor.
10. *Frontipoda americana* Mar.
11. *Oxus intermedius* new species
12. *Hygrobates ruber* new species
13. *Unionicola crassipes* (Müll.)
14. *Unionicola abnormipes* (Wol.)
15. *Unionicola ypsilophora* var. *haldermani* (Piers.)
16. *Unionicola intermedia* var. *wolcotti* (Piers.)
17. *Neumania tenuipalpis* Mar.
18. *Neumania punctata* Mar.
19. *Neumania ovata* Mar.
20. *Neumania semicircularis* Mar.
21. *Neumania brevibranchiata* Mar.
22. *Neumania okobojica* new species
23. *Koenikea concava* Wol.
24. *Piona reighardi* (Wol.)
25. *Piona pugilis* (Wol.)
26. *Piona inconstans* (Wol.)
27. *Piona spinulosa* (Wol.)
28. *Piona rotunda* (Kram.)
29. *Xystonatus asper* Wol.
30. *Arrhenurus marshalli* Piers.
31. *Arrhenurus megalurus* Mar.
32. *Arrhenurus manubriator* Mar.
33. *Arrhenurus laticaudatus* Mar.
34. *Arrhenurus laticornis* Mar.
35. *Arrhenurus lyriger* Mar.
36. *Arrhenurus trifoliatus* Mar.
37. *Arrhenurus americanus* Mar.

PLATES

PLATE I

Fig. 1. *Oxus intermedius*, dorsal view
Fig. 2. *Oxus intermedius*, lateral view
Fig. 3. *Oxus intermedius*, ventral view
Fig. 4. *Diplodontus americanus*, genital area of the nymph
Fig. 5. *Hygrobates ruber*, ventral plates of the female
Fig. 6. *Hygrobates ruber*, genital area of the male
Fig. 7. *Hygrobates ruber*, right palpus

PLATE I

PLATE II

Fig. 8. *Diplodontus americanus*, the two eyes of the left side
Fig. 9. *Hydryphantes tenuabilis*, ventral view
Fig. 10. *Neumania tenuipalpis*, genital area of the female
Fig. 11. *Neumania okobojica*, ventral plates of the female
Fig. 12. *Neumania okobojica*, palpus

PLATE II

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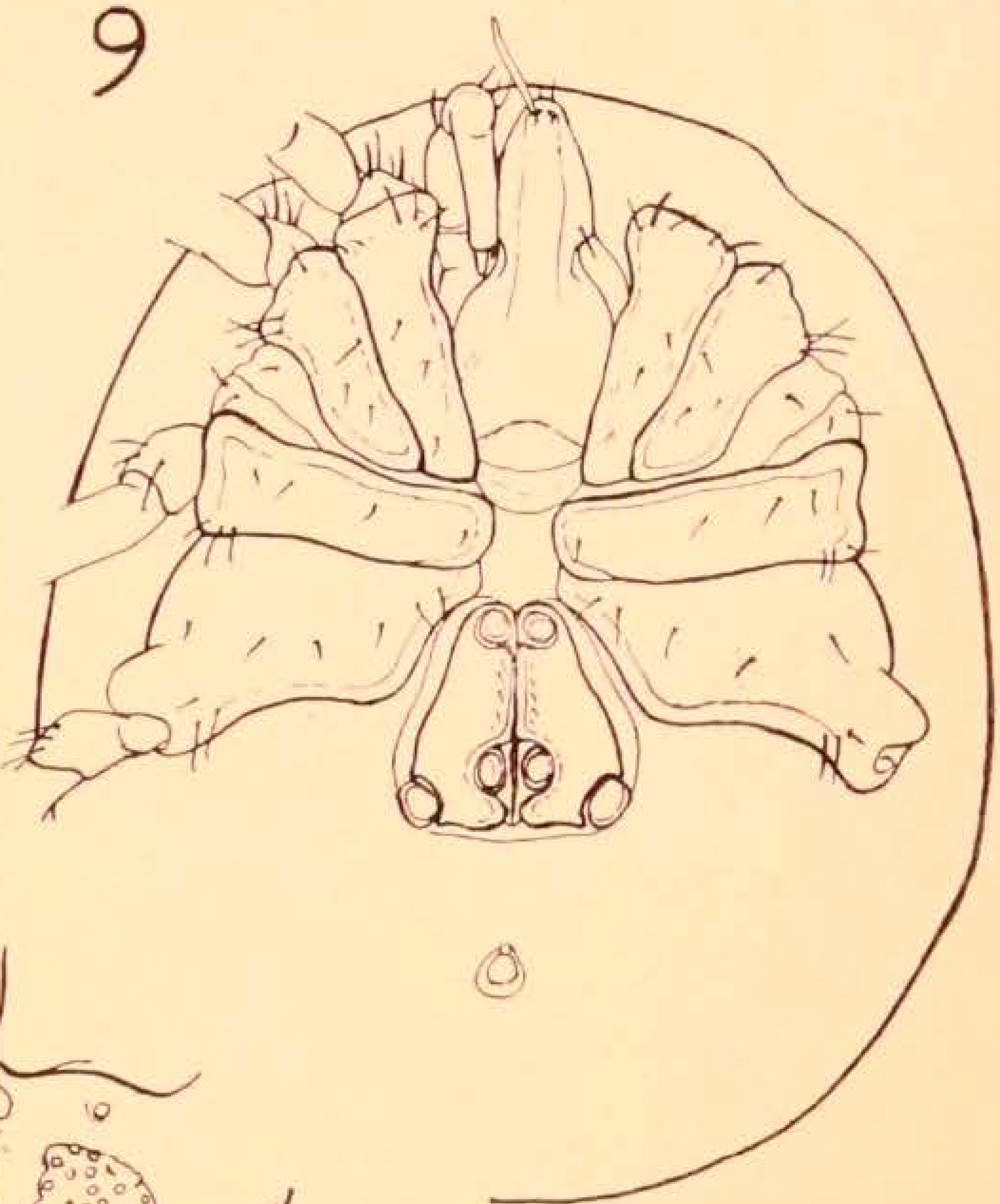

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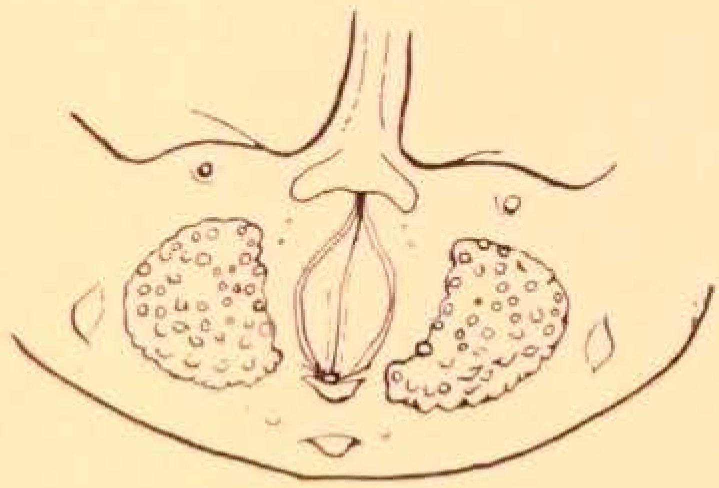

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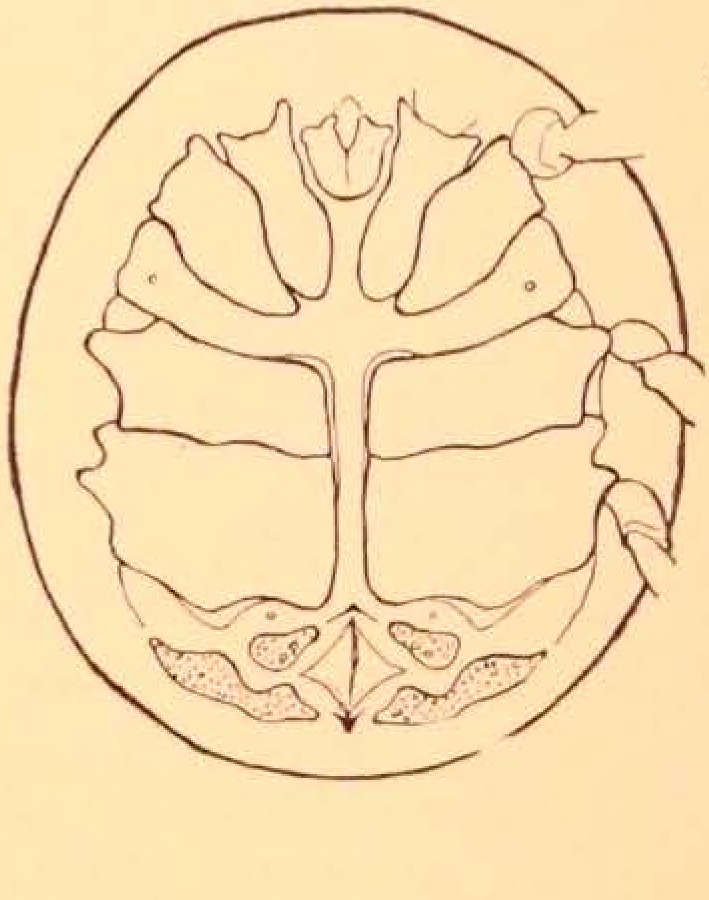

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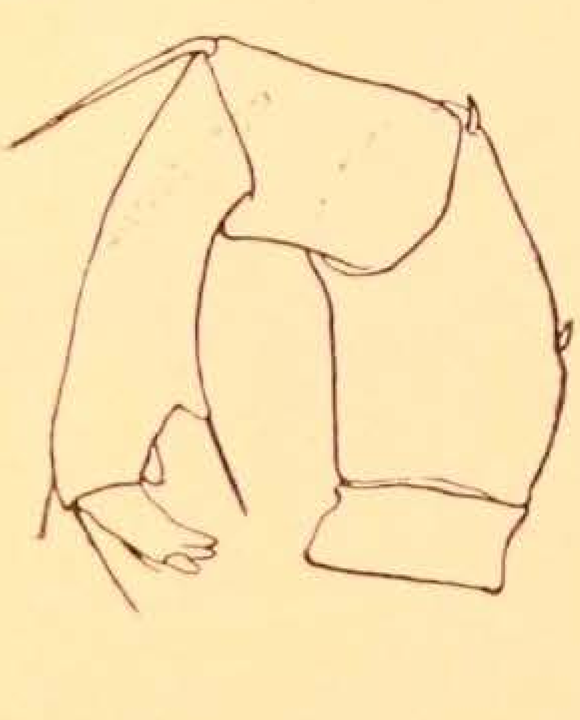
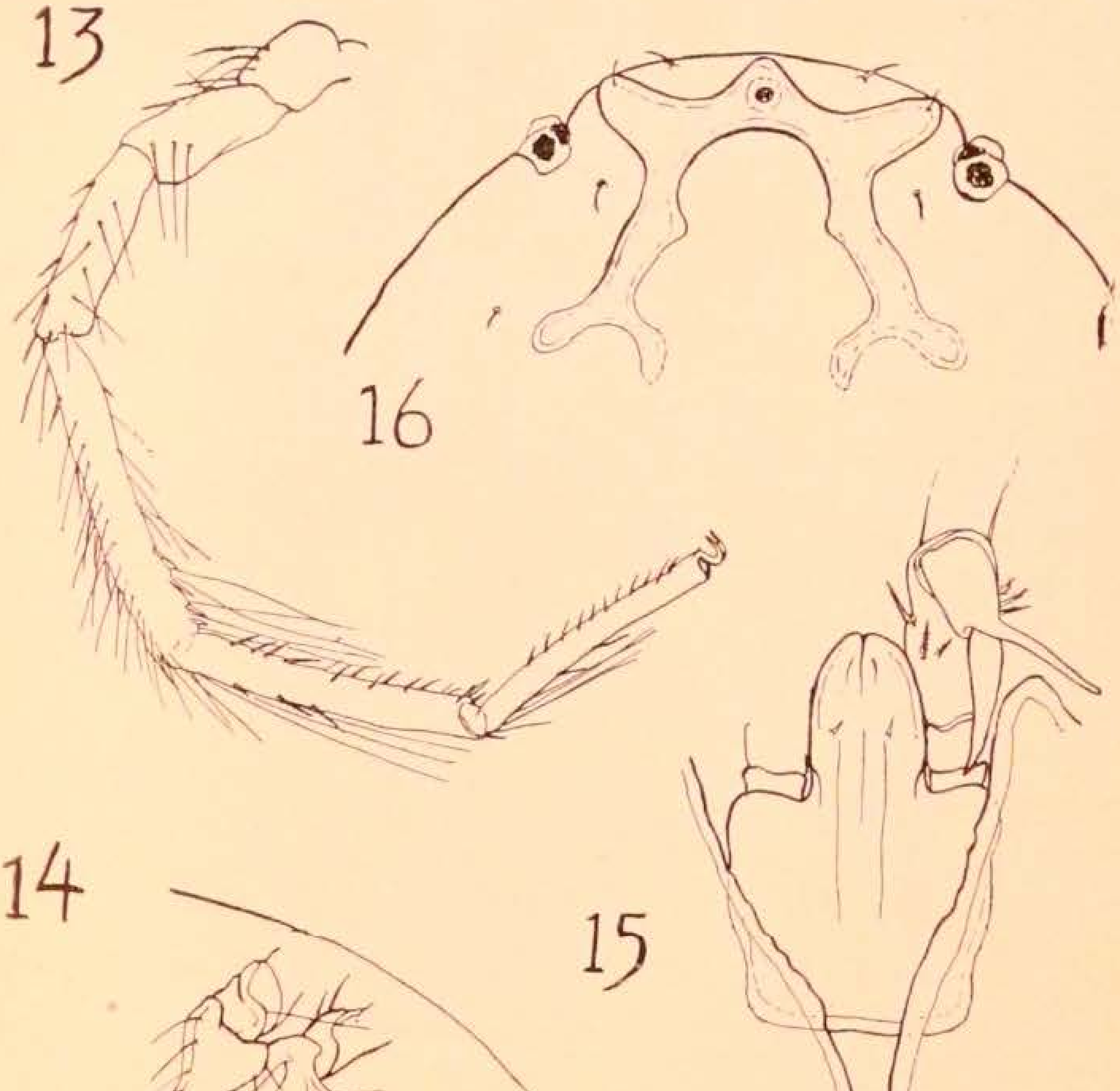


PLATE III

Fig. 13. *Diplodontus americanus*, fourth leg
Fig. 14. *Diplodontus americanus*, ventral plates, left side
Fig. 15. *Diplodontus americanus*, capitulum and left palpus
Fig. 16. *Hydryphantes tenuabilis*, eye plate
Fig. 17. *Hydryphantes tenuabilis*, palpus
Fig. 18. *Hydryphantes tenuabilis*, genital area of the nymph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