UM Libraries Depository

103274902014

THE GIFT OF

Author

This Thesis Has Been

MICROFILMED

Negative No. T-

665

Form 26

Approved for Master's Thesis. Hill
G. before May 5-1902

Anatomy of *Ascidia viridis* n. sp.

by

Horner Allen Hill

Missouri State University
May 1902

Anatomy of *Ascidia viridis* n. sp.

All the observations for this description were made from specimens preserved either in formalin or piero-formalin.

The formalin specimens, which were left in the test, were found to be in the best condition.

Those preserved in piero-formalin were more or less contracted.

The material was collected by Dr. George Sefere in the harbor of Beaufort N. C. during the summer of 1901. It was dredged up in water from three to six fathoms deep, and was found in great abundance. Frequently the individuals adhere in small clumps, but are easily separated.

In every case where examination was made the branchial sac was found to harbor a small amphipod (species undetermined).

Diagnosis of species

Body attached, sessile

Branchial and atrial apertures
not close together; each 8 lobed
(Counted with microscope test removed)

Test rather tough

Mantle, delicate on left side,
muscular on right side and
over siphons.

Branchial sac, not plicated;

not folded on itself posteriorly.
Internal longitudinal bars papillated,
stigmata straight.

Nerve ganglion and renal gland
distant from dorsal tubercle

Dorsal Lamina a simple
membrane, transversely ribbed.
edge slightly crenate; it
is continued behind the
oesophageal aperture

Tentacles simple, numerous.
(about 40)

Alimentary Canal on left side
of branchial sac

Gonads in the intestinal loops

General Description

This form in shape is not unlike that of *Assidiatenua* which is given by Herdman as the shape of a typical ascidia. The body is oblong, flattened laterally, the posterior end is rounded, the anterior end is rather blunt and slightly narrowed (Fig 1). It is attached, often to the inside of a fragment of Lamellobranch shell, by the posterior left side.

The branchial aperture is circular, terminal and median. The atrial aperture is elliptical, on the dorsal border, almost half way between the anterior and posterior ends: it is directed slightly posteriorly. There are no defined lobes around either aperture. Though the surface is raised somewhat, and irregular, in those regions. The entire surface is smooth but marked by irregular and

¹ Herdman, W.A., 1882, Report on the Tunicata collected during the voyage of H. M. S. Challenger during the years 1873 to 1876. Part I, Ascidian Simpliciter.

unequal pinous and elevations:

The color is pale, whitish yellow:
the length of the body is 7 cm., the
breadth 4 cm., the thickness 3 cm.

The Test

The test varies in thickness
from 2 to 5 mm.: it is a very
little thicker on the left side than
on the right: the thickest portions
are around the apertures, and the
thinnest over the place of attachment
to the shell.

It is gelatinous, almost cartilaginous
but translucent so that, in life,
the loops of the intestine may be
dimly seen through the test.

Blood vessels may be clearly
distinguished from the interior.

Two blood vessels from the body
proper enter the test at a point
just beneath the atrial siphons
and quite low on the left side.

From there they branch out in
all directions gradually becoming
smaller and terminating in
coarse capillaries, each of which
shows a terminal ampulla

(Fig 2). The ends of the main
branches, thus terminated, are
on the right side

A cross section of the Test shows a matrix with closely set bladder cells, and a few pigment cells.

(Fig 2). Objects, such as small *Lamellibranchs*, annelid worms, and sand particles are found imbedded in the test. ~~Also~~ The larger portion of the surface is also covered by a form of hydroid with its roots slightly imbedded.

Descriptive
of the Body
(test removed)

On splitting open the Test the body proper is easily removed. It is attached very loosely, by the blood vessels, and at the siphons. The general shape is that of the outside of the Test (Fig. 3. a & b). The drawing shows the siphons considerably contracted, due to the effect of the preserving fluid. The length of the body after it has been removed is 5 cm., the ^{height} ~~breadth~~ is $2\frac{1}{2}$ cm. and the thickness 1 cm. These dimensions and those given above apply to the larger specimens.

The most prominent feature of the right side is the musculature. (Fig. 3. - b)

The mantle on this side, and over the siphons (extending back to the intestinal loop, from the oral siphon, on left side) is composed of a network of muscles without any apparent arrangement, except over the siphons where they seem to be arranged quite systematically into longitudinal and circular muscles.

The circular muscles are nearer the exterior than the longitudinal. (Figs. 4 & 5)

Each muscle of the mantle is made up of a bundle of very fine fibrillae, quite loosely enclosed in a sheath or sarcolemma. (Fig 6)

No muscular striations have been observed. In none of the sections in which muscles were cut transversely ~~in a row of them~~ did the fibrillae appear circular.

(Figs 18, 20, & 21). A vertical section of the mantle (Figs 20, 21) shows that the majority of the muscles are situated near the inner edge, and that the outer part is composed of connective tissue.

with blood spaces in every part and bounded by the ectoderm. Each aperture has eight small and unequal lobes!

The oral siphon is lined by a thin layer of Test extending down to the tentacular ring.

The tentacles are situated at the opening into the branchial chamber at the base of the oral siphon; they are placed in one very thickly set row upon a muscular ring, and extend into the cavity, but appear to be able to bend back and forth through the opening.

They are simple, practically of one size, about one hundred and forty in number (Fig. 7)

The atrial siphon is slightly shorter than the oral and extends a little to the right of the median line.

' In Herdman's Revised Classification of the Tunicata, the author gives a note in which he makes mention of *Ascidia decemplex*, from the Malay Archipelago, which has ten lobes ~~round~~ on each aperture (Described by Shuter)

at its base it is provided with quite closely arranged, strong circular muscles. The sphincter

The longitudinal muscles converge toward the orifice. On the inner surface of this siphon are found scattered papillae, short ^{but} becoming longer in region of sphincter, with the point directed toward the aperture. (Fig 5) There are none of these papillae in outer half of siphon.

Many of these, as well as the tentacles in oral siphon, are filled with blood corpuscles (Fig. 7)

The atrial cavity is a comparatively thin space surrounding the large branchial sac.

The branchial cavity extends ~~the entire~~ ^{throughout} the entire length and breadth of the body. The branchial wall is attached on the left side by septa and blood vessels, extending across the atrial cavity, to the viscera.

On the right side quite strong septa connect it in the same way with the mantle.

9

The Branched
Sae

The structure of the branched wall is complex. In the innermost plane are found the internal longitudinal bars (Fig. 8) having quite regular papillae on one side. Just opposite each papilla there is a short duct which connects the longitudinal bar with the transverse vessel.

The transverse vessels, in a plane more exterior, are not of exactly equal size, but there is evidently no regularity about the arrangement of the large and small vessels.

In a third and still further exterior plane are found some of the fine longitudinal vessels and a part of the stigmata: from three to five appearing in each mesh.

The stigmata are not uniform either in size or shape. They are ciliated (Fig. 9) and lined with branched epithelial cells. The rest of the fine longitudinal vessels and the remainder of the stigmata are arranged in rows perpendicular to the row shown in Fig. 9. The wall is thus quite thick, and

The cut ends of all the fine longitudinal vessels, in each mesh, appear, in cross section, to form a quadrangle with one end open (the outer surface of the wall)

(Fig. 10) This section cuts across one of the transverse vessels at a very oblique angle. At ~~x~~ it passes between the ends of the transversely arranged rows of stigmata which gives the appearance of one large vessel.

A similar section in another place would show also the external¹ transverse vessels (Fig. 11)

A fourth plane from the inner and quite near the outer surface shows a network of blood vessels (Fig. 11) . b and c in Figs. 10 and 11 are the corresponding spaces between the vessels. Between each of the external transverse vessels is a short transverse vessel connecting the two rows of fine

¹ Called external transverse vessels to distinguish them from the transverse vessels shown in Figs 8. 9 & 10.

longitudinal vessels which border adjacent meshes.

(Fig. 11. s.t.u) Fig. 10. (s.t.u) shows how the section passed through one of these short connecting vessels.

There is a slight variation in the branchial wall in different regions. Sometimes three or four of these short transverse vessels occur. In every case they extend beyond the final longitudinal vessels which they connect, somewhat resembling papillae.

One of the cut septa which connect the branchial wall with the mantle may be seen in Fig. 10. (septa)

the position of the endostyle is typical. It connects anteriorly with the peribranchial groove (Fig. 12) which extends around the oral siphon, and unites again to form the epibranchial groove in the dorsal region. ^(the endostyle) It is quite a deep groove with edges free and flaring.

It extends ventrally around the posterior end of the branchial sac, then forward dorsally to the oesophageal aperture.

It may be seen in the wall of the oesophagus from the exterior (test removed)

The endostyle in cross section shows a thick lining or epithelial pad which reaches nearly to the free edge of the sides (Fig. 13). This epithelial pad, on each side of the groove, is thrown into short transverse folds (Figs 12 & 13)¹. Long flagella arise from the bottoms of the groove. Short cilia are found on the sides for a short distance, about half way down and over the free edges.

Branchial epithelium begins where the epithelial pad leaves off and continues over the outside to the point of union

¹ This condition is possibly artificial. It was observed, however, in both the formalin and picro-haematoxylin material.

with the branchial wall and then continues ventrally around the endostyle (Fig 13)

The ventral edge of the endostyle forms the upper wall of the atrial cavity in this region.

From an extreme posterior, ~~median~~ point to the oesophagus the endostyle is considerably modified; the epithelial pad is wanting; there are no long flagella; the sides are unequal, shorter without cilia, while the very bottom is lined with short cilia (Fig 14)

The dorsal lamina is a narrow membrane, extending from the posterior end of the epibranchial groove to the posterior end of the branchial sac. It becomes narrower ^{behind} ~~back of~~ the oesophageal aperture. The lamina and endostyle meet at the point where the endostyle becomes modified.

The left edge of the endostyle continues forward as the lamina; the right edge

continues forward as the right, and longer, side of the modified endostyle.

The other (left) side of the modified endostyle arises between these two at the point of divergence. (posterior, median point of branchial sac)

Near the base of the dorsal lamina is a short fold, which, with the lamina as one side, forms a more or less irregular groove, or canal. These two grooves continue forward to the oesophagus, parallel to each other, each one forming the boundary of a large dorsal groove (Fig 14). This dorsal groove is lined with a slightly modified branchial epithelium.

Short cilia are found only on one side of the fold near base of lamina and extending out from this a short distance (Fig 14).

Anterior to the oesophageal aperture the lamina is broader, but the dorsal groove is not so wide and it is not bounded on either side by a smaller groove.

(Fig. 15) a few short cilia are found near base of lamina and also on one side of a small fold at the distal edge from lamina.

The dorsal lamina is not a perfectly straight membrane but is curved to the right.

The transverse ribs are on the left, or convex, side. The expanded portion of the rib does not extend quite half way to the free edge but a much narrowed, fold or rib does continue (Figs 14 & 16).

The free edge is not plain but slightly crenate.

The Heart

The heart is similar to the heart of other ascidians. It is a long circular tube, extending on the ventral edge, from a point ~~at the level~~ ^{at the level} with the end of the anterior loop of the intestine, back around the posterior end of the body, to a position ^{at} ~~even~~ with the dorsal end of the stomach.

Most of the heart is visible only on the left side, ^{but} a small portion may be seen only on the right side (Fig. 3. 286).

The wall presents an irregular spiral, or folded, appearance.

Although it is not the same, yet ^{it is} similar in appearance to the heart of *Perophora amurens* described by ~~William~~ E. Ritter¹

On the side of the heart is a light colored spherical mass (sometimes two) which moves freely from one end to the other, apparently forced along by the pulsations. The nature of this body was not determined.

Blood circulation

In general the blood vessels are quite well defined tubes.

Numbers of these vessels are cut across in removing the branchial ^{wall} from the viscera on the left side. Two of the largest vessels in the body lead from a point near the anterior end of the heart out into the Test (Fig. 3, a) A ventral vessel is

¹ Proceedings of the California Academy of Sciences, Second Series, Vol. IV, *Gymnastrea* of the Pacific Coast of North America. *Perophora amurens* n. sp. (page 37) (issued Sept. 28 1894)

situated beneath the endostyle (Fig. 13) and a partially defined dorsal vessel above the lamina and dorsal groove (Fig. 14 & 15).

There are, however, blood spaces in every part of the body where the blood may flow freely without being confined to definite channels. Such blood spaces are in the mantle (Figs. 18, 20, 21); in the wall of the stomach and intestine (Figs. 26 & 27); throughout the minute structure of the intersiphonal organs (Fig. 18, 22) and among the ^{lobules} ~~glands~~ of the reproductive organs.

Throughout all these spaces and in the course of all the blood vessels appear innumerable blood corpuscles.

These corpuscles are light green and, in life, on account of their great numbers, they give the body a decided green color. It is possible that they are not blood corpuscles at all, but a ~~low form of~~ green alga, living symbiotically.

in the blood. They appear singly and collected in groups of six or more (Figs 14, 15, 20 & others)

Many of them show nuclei but others no nucleus can be made out. They are round but not all of equal size under the high power (60x immersion) each one appears to be a colony. Probably they represent a form of protococcoids.

Inter-siphonal
Organs

The dorsal tubercle, the epibranchial groove, the nerve ganglion and renal gland are all present (Fig 7)

The distance from the posterior end of the epibranchial groove to the anterior end of the ganglion is not quite equal to the distance from the same point to the dorsal tubercle; which latter distance is the length of

' One objection to considering them protococcoids is the fact that after the material has been imbedded, sectioned, and mounted, with the ordinary staining & dehydration process, the green color (presumably chlorophyll) persists

the epibranchial groove.

The dorsal tubercle is situated near the Tentacular ring and at the place where the peripheral groove enters the epibranchial

It is shifted a little to the right of a line drawn longitudinally through this groove.

(Fig. 17) The openings of the tubercle have an epithelial lining and are ciliated.

(Fig. 18) The character of the epithelium and the length of the cilia vary in different regions.

The duct of the renal gland leads directly into the tubercle dorsally. It is imbedded in the mantle near the lower surface below the anterior nerves.

(Fig. 18 & 21). It has an epithelial lining throughout its entire length.

The ^{nerve} ganglion is situated dorsally about one third of the distance between the siphons.

The relative position of the ganglion and renal gland is somewhat

similar to that in *Asidiamentula*!

The gland lies beneath the ganglion and projects beyond it at each end and on each side. (Fig 19)

But it is asymmetrically situated: The ganglion does not lie over the median line of the gland. At the anterior end the gland projects on the left side and not on the right, while at the posterior end the condition is just reversed.

The larger mass of the gland is on the right side.

A transverse section (Fig 20) through the anterior end of ganglion shows the gland underneath on the ~~left~~ side, extending only to the median longitudinal line.

Notes on the Morphology of the
Tunicata by Maynard
 Metcalf. Baltimore Md. 1900
 Zool. J. Chrb. alth. f. Anat. u. Ont.
 Bd. 13, 1900

A similar section through the posterior end would show the same relative, but reversed position.

Blood sinuses completely surround the gland and ganglion. They are also inclosed by the atrial epithelium which lines the mantle (Fig 20)

The large lumen of the neural gland is situated close to the ventral side of the ganglion, part of it lying beneath the anterior end and also extending back beyond the posterior end (Fig. 21) The figure does not show a median section. Blood vessels of the branchial wall appear beneath and at the side of the gland (Fig 20)

The duct of the neural gland is continuous with ~~opening of~~ ^{aperture of} this lumen anteriorly directly beneath the base of the nerve.

I have not been able to demonstrate a nephridial duct posteriorly, either by longitudinal or transverse sections.

The nerve ganglion is elongated

with its long axis in the long axis of the body (Fig. 19)

It is quite firmly attached to the branch by connective tissue. Four nerves are given off anteriorly and four posteriorly. These do not originate in the ^{same} ~~same~~ transverse line at either end. The ganglion extends further anteriorly on the left, and posteriorly on the right side (Fig. 19). The same general description is true for the renal gland with regard to its shape.

Fig. 22 shows the relative position of the anterior nerves, duct and gland. The different size of the nerves in this section may be understood by an inspection of Fig. 19.

The epibranchial groove is ciliated (Fig. 18). Its inner surface ~~of the groove~~ is not regular but is thrown into longitudinal folds, which are apparently continuations of the peripheral gill bands.

Digestive System

The digestive tract is visible only on the left side.

The intestine is large and makes a double loop, which occupies all of the space dorsally, and nearly all the space antero-posteriorly, having the shape of an ~~large~~ S turned backward.

The oesophagus and anus are ~~each~~ placed dorsally. The anus opens into the atrial cavity near base of the atrial siphon.

The oesophagus is situated back of the atrial siphon, a little to the left of the median line, about $\frac{2}{3}$ of the distance from the anterior to the posterior end of the body. The oesophageal aperture opens out of the branchial cavity and becomes much smaller just outside of the branchial wall.

The dorsal groove, described above, is in direct communication with this funnel shaped oesophageal opening. After this constriction the

Oesophagus gradually widens again as it enters the stomach (Fig. 3. a)

The stomach is an elongated circular sac, situated in the posterior part on the left side of the body - only the heart being more posterior (Fig. 3. a) The long axis is placed dorso-ventrally with either end constricted: dorsally into the oesophagus; ventrally into the intestine. The posterior loop of the intestine lies over the anterior edge of the stomach thus giving the stomach from the exterior a crescent shaped appearance.

The inner surface of the stomach is thrown into longitudinal folds ^(Fig. 23) ~~these~~ ^{which} are larger on the right side.

The folds just described converge into the end of the typhlosole which arises at the beginning of the intestine and continues throughout its entire length. It is placed ventrally except in the loops

Stomach (Fig. 26)

In the wall of the intestine between the loops, both male and female gonads are found together. (Fig. 24)

The ova appear in all stages a layer of follicle cells surrounds each ovum which clearly shows the nucleus and nucleolus. (Fig. 25).

The male lobules are filled with minute round spermatozoa (Figs. 24 & 26)

The spermatozoa, seen in a cross section of the vas deferens are very small, elongated and provided with a minute short flagella.

The oviduct arises from a network of small tubes which ramify among the ovaries, and follows the posterior loop of the intestine around to the anus (Fig. 3.9)

The vasa efferentia unite in the right wall of the intestine at about the point where the oviduct first becomes visible. The vas deferens then

follows the course of the oviduct, but a little below and slightly in front of it. This may be seen after careful inspection.

These terminate at the same place near the end of anus and have fluted lips (Fig 24). In several individuals observed the vas deferens was filled with spermatozoa and the oviduct filled with eggs. Thus apparently both maturing at the same time!

Renal system

The wall of the stomach is filled with spherical bodies, the renal vesicles containing concretions. These are more abundant in the right wall and over the end of the typhlosole. In the regions named, after the stomach has been stained in borax carmine, these vesicles are so numerous and so closely set that they render the wall quite opaque.

Dr. Lefevre demonstrated, in Beaufort, that self-fertilization is possible in this ascidian, and embryos thus produced were raised into larvae.

The proportion of eggs fertilized in this way is not as great, however, as in cross-fertilization, and more abnormalities occur.

In the left wall of the stomach they appear in great numbers but are more scattered (Fig 27)

They appear also throughout the entire length of the intestine, even among the gonads wherever they occur. (Fig 24)

I have made only a cursory examination of the ~~connections~~ ^{vesicles}. Evidently the treatment given the sections containing them was not adapted to the bringing out of the details of their finer structure.

Their general appearance is that of a large round vesicle with a darker staining body enclosed. Frequently more than one collection may be seen within a single vesicle. The surface of each vesicle shows polygonal cells of pavement epithelium (Fig 27). Fig 26 shows a characteristic appearance of the renal connection & vesicle in section.

The general structure is that of concentric rings which, in some cases, lie so close together as to leave no space between them, as seen in the figure.

They do not all show a double center.

Systematic
position
in
Herdman's
Classification

Class - Tunicata

Order - Ascidiacea

Suborder - Ascidiacea Simplex

Family - Ascidiidae

Subfamily - Ascidiinae

Genus - *Ascidia*

Species - *A. viridis*

Methods.

For total preparations, the material was stained in borax carmine. The sections were stained with haemalum.

For Fig. 19 a slight differentiation of nerve and muscle was effected by staining with borax carmine with thorough washing, and afterwards staining with $\frac{1}{2}\%$ aqueous acid fuchsin and washing out in water.

Explanation of Plates

All of the figures excepting
1. 3. 7. & 8x were outlined
with the camera lucida

Plate I

- Fig. 1 Whole specimen, *Ascidia viridis*
(photograph)
- Fig. 2. Cross section of test. X 525
- Fig. 3. Body removed from test
natural size. a, left side
b, right side
- Fig. 4. Portion of wall of oral siphon.
seen from interior, with the
test lining removed. X 70
- Fig. 5. Portion of atrial siphon, seen
from the interior X 85
- Fig. 6. Broken end of muscle from
mantle on right side. X 85
- Fig. 7. Pharyngeal ^{opening} ~~apparatus~~ and
inter-siphonal organs.
the oral siphon, above the tentacles
has been removed. the tentacles
ring then cut and spread out
with the tentacles directed outward
X 10 (seen from the interior)

Fig. 8. Portion of branchial wall
seen from interior $\times 85$

Fig. 9. Small portion of branchial
wall (tangential section) $\times 525$

Fig. 10. Transverse section branchial wall
 $\times 70$

Fig. 11. Tangential section of same, near
outer wall $\times 85$

Fig. 12

Plate II

Fig. 12. Union of endostyle and
peribranchial groove. $\times 70$

Fig. 13. Cross section of Endostyle $\times 85$

Fig. 14. Coronal section, dorsal region
of branchial sac, back of
oesophageal aperture $\times 85$

Fig. 15. Cross section of same,
anterior to oesophageal aperture
 $\times 85$

Fig. 16. Dorsal lamina $\times 70$

Fig. 17. Dorsal Tubercle, inner view
 $\times 70$

Fig. 18. Longitudinal, vertical section
of dorsal Tubercle, showing
cut side of epibranchial groove (e.g.)
with folds (continuations of peri-
branchial bands) $\times 70$

Fig. 19. Nerve ganglion and neural gland, seen from exterior of branchial wall (part of the muscles removed) $\times 50$

Plate III

Fig 20. Transverse section of ganglion and gland. showing also thickness of the mantle $\times 70$

Fig. 21. Longitudinal, vertical section of ganglion and gland (the section is not a median section) $\times 70$

Fig. 22. Section same as fig 20. only more anterior. (details not filled in) $\times 70$

Fig 23. Cross section of wall of stomach. showing folds on right side (l). inner surface $\times 70$

Fig. 24. Arms. also the end of oviduct & vas deferens $\times 50$

Fig. 24. Portion of cross section of wall of intestine. showing male & female gonads in trabeculae of connective tissue $\times 80$

Fig 26. Cross section upper
wall of stomach showing
male gonads, & renal vicle.
~~connection~~ x 525

Fig 27. Upper wall of stomach
(small portion) seen
from interior. x 18
(the blood vessel & one vesicle x 20)

Reference Letters

- a. = anus
 a.ep. = atrial epithelium
 am. = ampulla of blood vessel in Test
 a.s. = atrial siphon
 b.c. = blood capsule
 b.ep. = branchial epithelium
 b.s. = blood sinus
 b.v. = blood vessel
 c.d. = connecting duct of internal longitudinal bar
 cm. = circular muscle of siphons
 d. = duct of renal gland
 d.b.s. = dorsal blood sinus
 d.l. = dorsal lamina
 d.t. = dorsal tubercle
 ect. = ectoderm
 e.g. = epibranchial groove
 en. = endostyle
 ep.p. = epithelial pad
 et.v. = external transverse vessel of branchial wall
 f. = fibrilla of muscle bundle
 f.l.v. = fine longitudinal vessel of branchial wall
 fl. = flagella
 g. = nerve ganglion
 gl. = renal gland
 ht. = heart
 i.l. = internal longitudinal bar of branchial wall

Reference Letters (continued)

- int. = intestine
 l.m. = longitudinal muscle
 lu. = lumen of renal gland
 m. = muscle
 n. = nerve
 O. = ovary
 oe. = oesophagus
 O.S. = oral siphon
 ov. = oviduct
 p. = papilla
 p.e. = pigment cell
 p.p.g. = peripharyngeal groove
 r.c. = renal concretion
 s. = stigma of branchial wall
 sep. = septum
 st. = stomach
 t. = testis or testes
 tr.m. = transverse muscle
 tr. = tentacle
 t.r. = transverse rib of dorsal lamina
 t.v. = transverse vessel of branchial wall
 v.d. = vas. deferens
 vs. = vesicle of renal concretion
 v.v. = ventral vessel (blood)

Synopsis of contents

	Page
Collection & preserving material	1
Diagnosis of the species	2
General description	3
Test	4
Describing body (Test removed)	5
a nomenclature	5
b Openings	7
c Cavities	8
Branchial Sac	9
a Endostyle	11
b Dorsal Lamina	13
Heart	15
Blood Circulation	16
Intersiphonal Organs	18
a Dorsal Tubercle	19
b Nerve Ganglion	19
c Nerve Gland	20
Digestive System	23
Reproductive Organs	25
Renal System	27
Classification	29
Methods	29
Explanation of Plates	30
Reference Letters	34

3781M71
XH55

RECEIVED
NOV 29 1908
UNIV. OF MICH.

~~This thesis is never to leave this room.~~
~~Neither is it to be checked out overnight.~~