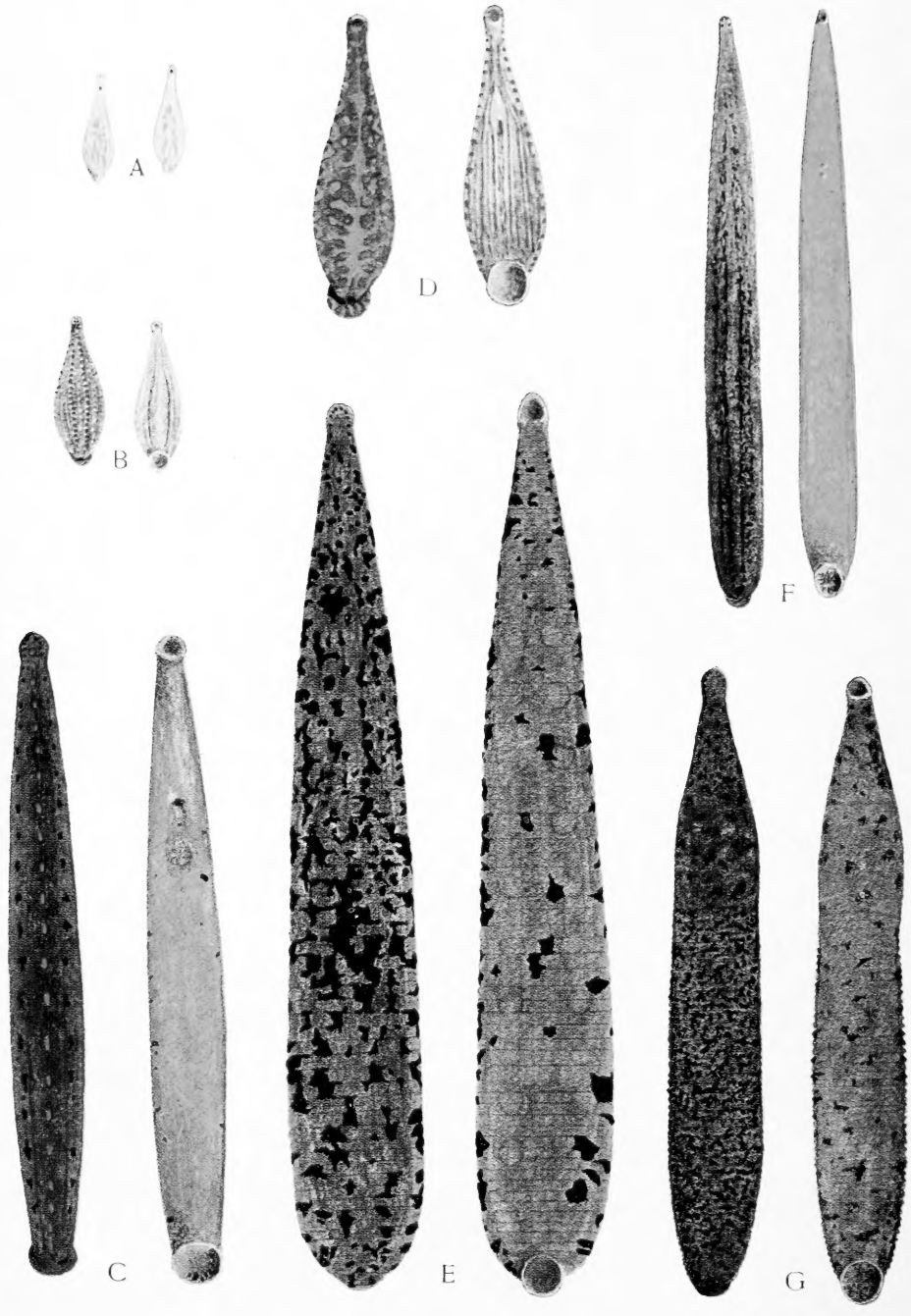


A--Glossiphonia stagnalis
B--Glossiphonia complanata
C--Macrobdella decora
D--Placobdella parasitica
E--Haemopis grandis
F--Erpobdella punctata
G--Haemopis marmoratis

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
HENRY F. NACHTRIEB ZOOLOGIST

THE
LEECHES OF MINNESOTA

PART I. GENERAL ACCOUNT OF THE HABITS AND STRUCTURE OF LEECHES
BY
HENRY F. NACHTRIEB

PART II. ANATOMY OF PLACOBDELLA PARASITICA
BY
ERNEST E. HEMINGWAY

PART III. CLASSIFICATION OF THE LEECHES OF MINNESOTA
BY
J. PERCY MOORE

ZOOLOGICAL SERIES NO. V

JANUARY 1912
MINNEAPOLIS MINNESOTA

The Board of Regents of The University of Minnesota

Honorable John Lind, Minneapolis.....1914
The President of the Board.
George Edgar Vincent, LL.D., Minneapolis.....Ex-Officio
The President of the University.
Honorable Adolph O. Eberhart, Mankato.....Ex-Officio
The Governor of the State.
Honorable C. G. Schultz, Saint Paul.....Ex-Officio
The State Superintendent of Public Instruction
Honorable W. J. Mayo, Rochester.....1913
Honorable Milton M. Williams, Little Falls.....1913
Honorable Henry B. Hovland, Duluth ... .1914
Honorable A. E. Rice, Willmar.....1915
Honorable Charles L. Sommers, Saint Paul.....1915
Honorable B. F. Nelson, Minneapolis.....1916
Honorable Pierce Butler, Saint Paul.....1916
Honorable Charles A. Smith, Minneapolis.....1916

LETTER OF TRANSMITTAL

University of Minnesota,
December, 1910.

To The President of the Board of Regents of the University of Minnesota.

Sir:—I herewith submit to the honorable Board of Regents the manuscript of a report on The Leeches of Minnesota with the recommendation that it be published and distributed.

The general part of the report was written by myself. The special paper on Placobdella pediculata, a new species parasitic on one of our food fishes, was prepared by Dr. E. E. Hemingway while pursuing graduate studies in the Department of Animal Biology.

The systematic part of the report is based on the material and notes collected by the Zoological Survey in Minnesota and was prepared by Dr. J. Percy Moore, an American authority on leeches.

The report constitutes "Zoological Series, No. V" of the reports of the Zoologist of the Geological and Natural History Survey.

Very respectfully,
Henry F. Nachtrieb,
Zoologist of the Survey.

CONTENTS

STATEMENT

The material, notes and models upon which this report is basd are stord in the Department of Animal Biology of the University of Minnesota. All of the material was collected in Minnesota by and under the direction of the Zoologist of the Geological and Natural History Survey of Minnesota.

The original plan of the report contemplated a full account of the habits, gross and minute structure, development and relationships of the leeches in general and a classification of the leeches of Minnesota.

Professor Moore's report on the material sent to him for identification and description was receivd several years ago, but the publication of it could not be undertaken at that time. Shortly afterward Dr. Hemingway completed his thesis on Placobdella pediculata. It was then decided to add this thesis as a unit because it treats of a new species parasititc on one of our food fishes. The comprehensiv bibliografy prepard by Hemingway in connection with his work has been omitted and the general account, the anatomy, histology and embryology of leeches, has been reducd to very general terms.

This report on the leeches of Minnesota contains:—1) A general part,—the habits, economic importance, anatomy, development and relationships of leeches; 2) A special part,—an account of the anatomy of a new species found parasitic on one of our river fishes; 3) A systematic part,—a key to and descriptions of the species collected in Minnesota together with an account of their habits and distribution, so far as these are known. This part will enable any one to identify representatives of the species here describd. Specimens that can not be identified with any of the species describd in this report may be sent to the Department of Animal Biology, University of Minnesota, Minneapolis, Minnesota, for identification. Inquiries will receive prompt attention.

The publication of the report has been delayd for various reasons that have no vital bearing on the value of the report.

The plates were made by the Bureau of Engraving of Minneapolis.

The printing was done by the Index Press of Minneapolis.

PART I

General Account
of the
Habits and Structure of Leeches
by
Henry F. Nachtrieb

GENERAL INTRODUCTION

The leeches, also cald blood suckers by people in general and Hirudinea by the scientist, are distributed all over the world. They are mentioned in the writings of many of the ancients. Herodotus, who was born about 480 B. C. wrote about the leech under the name "bdella", which still forms the ending of some of our scientific names of certain leeches and groups of leeches. Galen, a Greek physician and author born about 130 A. D., recommended the use of the leech for bloodletting. Other Greek and Roman, German, French and English writers wrote about the leech and its habit of sucking blood, so that in a general way leeches became quite well known centuries ago. The medicinal leech in particular became well known thru a great many more or less extended writings on its anatomy and habits and was brought into almost universal use by physicians. It was continued in quite general use until about the middle of the 19th century. Altho this leech in particular was in such general use and it and others frequently became objects of scientific study, we did not get a correct conception of some of the most prominent features of leech structure until 1900. There is still much to be cleared up concerning the structure and life history of many of our leeches.

Habits.

Most of the leeches live in fresh water, under stones, leaves and wood, on water plants, in the mud and ooze on the bottom of ponds, lakes and streams, and attacht to other animals. A few live in salt water, a few in moist earth, and a few on land in the forests of tropical and semi-tropical countries. They can crawl about after the manner of the "measuring worms", using their suckers when thus moving about. Those living in the water are also good swimmers. They swim by graceful undulations of the body. Land leeches when dropt into the water usually sink to the bottom and then crawl out.

Many of the leeches feed on the blood of vertebrates. Some of the bloodsucking leeches remain attacht to their hosts only long enough to become gorgd with blood, and some apparently spend

most of their lifetime attacht to their hosts. The latter are confirmd parasites. The former are only temporary parasites, they living free and independent lives most of the time. Both groups are well represented in the lakes, ponds and streams of Minnesota. They are frequently found on turtles, fish, frogs and crayfish and sometimes on freshwater mussels, birds and mammals. Several species will attach themselves to man, some, especially when young, showing a preference for the tender regions between the toes.

Other leeches, like the common horse leech found in our lakes, are scavengers and carnivores. They feed on snails, small clams, worms, insect larvae, smaller leeches, ded fish, &c. They do not, as a rule, attach themselves to living animals for the purpose of sucking blood. When, however, the usual food is scarce some of them will feed on blood suckt from the animals to which they may become attacht. These are temporary or occasional parasites. This group is also represented in all parts of the state. It is fully as widely distributed as the true bloodsuckers.

Of the twenty one species collected in Minnesota and describd in this report eight are true bloodsuckers, four are blood and flesh eaters, six are flesh eaters and scavengers, and of three the habits are practically unknown. Of these some species are found in all parts of the state and others are found only in certain regions. A species may be very abundant in one locality and rare in another. Undoubtedly species now reported for only certain localities will later on be found in others, and species once abundant in some localities may now be rare or even absent in those localities. On the other hand, a species reported rare or wanting in some locality a few years ago may now be found abundant there. Their wide distribution is largely due to their habits. They are distributed or carried from one body of water to another by the migrating animals to which they became attacht and in the weeds and mud adhering to these animals, particularly turtels, birds and mammals. The eggs or very young enclosed in capsules attacht to water plants and other objects may also be carried from one place to another by birds and mammals and the wind.

There are, all told, a few more than one hundred species generally recognizd today. They are distributed all over the world.

Economic Importance.

In many places leeches are abundant enough to be of economic importance. They may be of value in so far as they serve as food for fishes and birds or in so far as they are scavengers. On the whole, however, the leeches are rather an injurious group. They may kill fishes and other animals, particularly the young by bleeding them to death or, indirectly, by devouring the snails, worms, larvae &c. which constitute the principal food of some fishes. They are also injurious in so far as they serve as intermediate hosts for various developmental stages of animals that during some period of their lifetime are parasitic on fishes, birds and other animals. There is still a great deal to be learnd about the life histories of many of our leeches, their relations to other animals, particularly their relations to fishes, and their influence on the character of the fauna in particular bodies of water.

The wounds made on man by the bloodsucking leeches very rarely produce any serious results. Considerable, sometimes intense, itching of the region immediately around the wound is usually the only noticeable effect. More serious results are probably due to infection. When, however, the leeches find their way into internal passages, they may produce serious disturbances. The young of the bloodsucking horse leech taken in by horses and cattle while drinking from ponds or lakes have been known to become attacht to the lining of the farynx and the windpipe and cause more or less serious disturbances. Fortunately the number of species that in this way practically become internal parasites is very small, and the chance of their invading human beings exercising some care is very slight. It may be well to remember, however, that it was a small inconspicuous leech, not thicker than a horse hair, that was the cause of considerable trouble to Napoleon in Egypt. His soldiers in drinking water direct from the streams and lakes and pools took in small leeches which attacht themselves in the back part of the mouth cavity and caused annoying blood spitting and difficulty in breathing. The small land leeches so much dreded in the forests of some countries (South America, Australia, Japan, Ceylon and others) are not found in Minnesota. What the introduction and acclimatization of such forms in our forests would mean may be inferd from the following account taken from Tennent's book on Ceylon:—Of all the plagues which beset

the traveler in the rising grounds of Ceylon, the most detested are the land leeches (Hæmadipsa ceylonica). They are not frequent in the plains, which are too hot and dry for them, but amongst the rank vegetation in the lower ranges of the hill country, which is kept damp by frequent showers, they are found in tormenting profusion. They are terrestrial, never visiting ponds or streams. In size they are about an inch in length and as fine as a common knitting needle; but they are capable of distension till they equal a quill in thickness, and attain a length of nearly two inches. Their structure is so flexible that they can insinuate themselves through the meshes of the finest stocking, not only seizing on the feet and ankles, but ascending to the back and throat, and fastening on the tenderest parts of the body. In order to exclude them, the coffee planters, who live among these pests, are obliged to envelop their legs in "leech-gaiters" made of closely woven cloth. The natives smear their bodies with oil, tobacco, ashes, or lemon juice, the latter serving not only to stop the flow of blood, but also to expedite the healing of the wounds. In moving, the land leeches have the power of planting one extremity on the earth and raising the other perpendicularly to watch for their victim. Such is their vigilance and instinct, that, on the approach of a passer-by to a spot which they infest, they may be seen amongst the grass and fallen leaves on the edge of a native path, poised erect, and prepared for their attack on man and horse. . . . Their size is so insignificant, and the wound they make is so skillfully punctured, that both are generally imperceptible, and the first intimation of their onslaught is the trickling of the blood, or a chill feeling of the leech when it begins to hang heavily on the skin from being distended with its repast. Horses are driven wild by them, and stamp the ground in fury to shake them from their fetlocks, to which they hang in bloody tassels. The bare legs of the palankin bearers and coolies are a favorite resort; and as their hands are too much engaged to be spared to pull them off, the leeches hang like bunches of grapes around their ankles."

One of our species, *Macrobdella decora,* has been used insted of the medicinal leech for bloodletting, but since bloodletting thru the leech is no longer considerd a cure for all ills this species can hardly be clast with animals beneficial to man.

The medicinal leech in the heyday of bloodletting was cultivated in great numbers in France, Hungary, Russia and other

countries. One American leech farm sold as many as 1000 or more a day. Today leeches are so seldom used that few young people have seen a medicinal leech, and most physicians of today do not know how to apply a leech properly. It is difficult to say how much leeches are still used because the leech industry has ceasd to be one of commercial importance. That they are, in comparison with former days, used very seldom is evident from the fact that where several thousand were employd fifty years ago there is scarcely one employd today. It has been estimated that France used about twenty five million in 1846. About 7 million were used in the London hospitals in 1863 and five to six million in the hospitals of Paris. Today one can not find a leech in most of our hospitals. Naturally the price of the medicinal leech has dropt. About eighty years ago medicinal leeches were worth $50.00-$75.00 per thousand. About fifty years ago they were worth $20.00-$40.00 per thousand and today they are not worth more than $20.00 per thousand with a very much restricted market.

Hirudo medicinalis, the medicinal leech, included a number of varieties that up to about the middle of the nineteenth century were almost universally used by the medical profession. When full grown and extended this leech is from eight to twelve inches long and about half an inch wide. The general or ground color is a dull yellowish brown to gray or greenish gray. On each side there may be an orange stripe borderd with black and, as a rule, the dorsal side is markt with six rust-red longitudinal lines spotted with black. The coloring, however, varies so much that at least sixty-four varieties basd on these minor differences have been describd. Among the most prominent of these are the socald German and Hungarian medicinal leeches. The German medicinal leech (H. medicinalis) is markt on the dorsal side with six longitudinal reddish lines and on the ventral side with black spots. The ventral side, however, varies from the spotted to an almost uniformly black coloring. This variety is the common one in the markets of Germany, France, Denmark, Sweden, Russia, England and America. The Hungarian variety is markt with only four reddish to brownish lines on the dorsal side and an unspotted olive green on the ventral side. This variety is found most common in southern and southeastern Europe.

The medicinal leech (of all varieties) prefers lakes and ponds having a clay bottom and a rich growth of plants. It swims about actively during the daytime and during its earlier years feeds largely on the blood of some of the socald coldblooded animals, like turtles and fish. When mature it feeds on the blood of socald warmblooded vertebrates.

The eggs are enclosd in oval coccoons about an inch long. The coccoons are deposited in the earth near the shore during June, July and August. The young come out six to eight weeks after the eggs are laid and do not become fullgrown until five years later. They are not of any value for bloodletting until three years old. Under favorable conditions they may live for more than twenty years.

When bloodletting was an almost universal practis various means were employd to make gorgd leeches disgorge the blood

in their digestive tracts so that they could be stimulated to renewd sucking on the next patient. Such treatment made every mature leech available for repeated operations within a short time. The practis was fraught with danger for the patients (danger of infection thru the leech's mouth); but it was a natural result. A leech gorgd with blood might be satisfied for many months. A study of its physiology and habits disclosd the way to greatly reduce this period of uselessness. Accordingly the pleasures of the sucker were multiplied by depriving him of the fruits of his labor for the financial benefit of his keeper. It is interesting to note that, as stated in Vol. II of the Cambridge Natural History, "The former extensive use of the leech has led to the transfer of its name to the doctor who employs it, the authors of the sixteenth century constantly terming a physician a leech; it has been suggested, however, that the term was applied rather by way of analogy."

Fortunately for humanity the general practis of bloodletting by means of *Hirudo medicinalis* is a practis of the past.

External Characters.

The leeches of Minnesota are easily recognizd by their external features. The most prominent of the external characters are a distinct sucker at the posterior end of the body and a more or less evident sucker or sucker-like differentiation around the mouth. When at rest the leech is elongated, more or less flattend dorso-ventrally, tapering gradually toward the anterior or mouth end and more abruptly at the posterior end. A fair conception of the general leech form can be obtaind from the frontispiece and plate A. The general outline of the leeches is quite uniform, the external differences being largely differences in color, color patterns, skin papillae and the arrangement of the annuli. The body is very muscular and can be much shortend, changd in shape or tightly rold up. Some species, when not swimming or crawling about, actively change their outlines, often assuming many odd shapes in comparatively rapid succession or holding some odd form for several minutes at a time. This is particularly true of some of the smaller, leaf-like leeches. When kept in aquaria they will often crawl up the sides of the aquaria until the anterior end is just below or near the surface of the water and will then begin a series of remarkable muscular exercises. These changes in form may have some pysiological significance, such as aiding the circulation of the blood and the lymph

and thus indirectly hastening excretion. The following outlines, Fig. 1, represent some of the more striking shapes assumd by one of the *Glossiphonidae.*

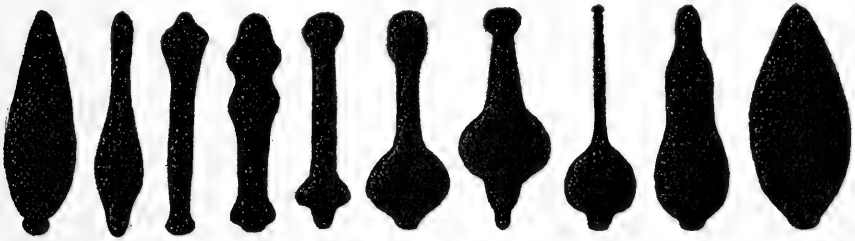


Fig. 1

These striking changes of form have not been observd among the more elongated, ribbon-like leeches. In these the change of form is practically limited to extension or elongation accompanied with a decrease in width and to a contraction or shortening in length accompanied with an increase in width.

Another characteristic external feature is a more or less evident annulation of the body. Nearly all leeches appear to be made up of a series of rings technically cald annuli. Such annulation or segmentation of the body is quite characteristic of a large group of worms cald annulata. This group includes a large variety of marine worms, some freshwater worms, the earthworms and the leeches.

A careful examination of our common earthworm, also cald angleworm, will disclose the fact that the internal organization is also segmented and that this internal segmentation corresponds to the external annulation. In other words, the annulation seen on the surface of the body represents a condition of the entire organization. For example, a ring in the middle region of the body is separated from the ring in front of it and from the ring behind it by a thin transverse partition at each end. Between these partitions, that is within the ring, there is a nerve centre and certain nerve fibers, a pair of excretory organs, muscles and so on. The same is true of the ring in front of this and the ring behind it. Indeed all the annuli, excepting a few modified ones of the anterior end and a few modified ones of the posterior end, are quite alike in their make-up. The earthworm, therefore, may be thought of as an animal made up of a number of similar rings or segments joind together end to end in a single row. Each ring or segment in such

an organism is technically cald a somite or metamere, and the condition of being thus built up is cald metamerism.

The earthworm presents metamerism in a relatively simple form. In the leeches, however, the external annulation does not correspond to the real metamerism. Each true somite or metamere includes several of the externally evident rings or annuli. Consequently the number of annuli in the leech is always greater than the number of somites or metameres.

Moreover, there are no evident partitions between the somites to aid in determining the limits of even a typical somite. But careful study has disclosd the fact that the nerves have definit relations to the annuli and that other internal structures present certain definit relationships, so that we now can determin the limits of the leech somite quite as definitly as we can those of an earthworm.

It is now generally accepted that the leech body is composd of thirty three or thirty four somites. The number of annuli varies considerably in the different species but the number of somites is always the same. This is one of the features in which the leeches differ from the other groups of annulata.

The limits of the somite adopted in this report are not those current prior to 1900. It is not necessary to give more than a brief discussion of the limits of the leech somite in this report since any one interested in the question can find a clear and full presentation of it in Castle's paper on "The Metamerism of the Hirudinea" in Vol. XXV, 1900, of the Proceedings of the American Academy of Arts and Sciences. This paper was reprinted as No. 108 of the Contributions from the Zoological Laboratory of the Museum of Comparative Zoology at Harvard College. Also in Moore's paper entitled "A Description of Microbdella biannulata with Especial Regard to the Constitution of the Leech Somite", which appeard in the Proceedings of the Academy of Natural Sciences of Philadelphia of 1900.

The earlier writers recognizd only the annuli, which they numberd consecutively from the anterior end back. They located structures by direct reference to the number of the annulus. In 1862 Gratiolet pointed out that the annuli of the medicinal leech are not all alike but that they are arrangd in similar groups (somites) within which are always found certain structures. Later it was generally admitted that the ganglia (groups of nerve cells

and nerve fibers) are definit internal criteria of the somites. Now in a leech having three annuli to a typical somite each ganglion gives off three nerves on each side to certain definit parts of the somite. Prior to 1900 the annulus carrying the dorsal sense organs of such a leech was considerd the first annulus of the somite. This annulus also containd the ganglion. The nerves coming from this ganglion, however, were distributed to the annuli of two somites.

Castle concluded from his observations that if the ganglion is an important element of a somite it is only natural to expect all of its nerves to be supplied to that somite, and accordingly he decided that the anterior or first nerve went to the first or anterior annulus, the second nerve to the second annulus, which contains the ganglion and bears the dorsal sense organs, and the third nerve to the third or posterior annulus. These limits also brought other internal structures into more satisfactory relationships and presented the somite in all details of structure as a complete unit in itself.

Moore had reacht the same conclusion independently.

In the accompanying diagram, Fig. 2, the somite as determind by Castle and Moore, and adopted in this report, is indicated on the right side and the limits according to the older writers are indicated on the left.

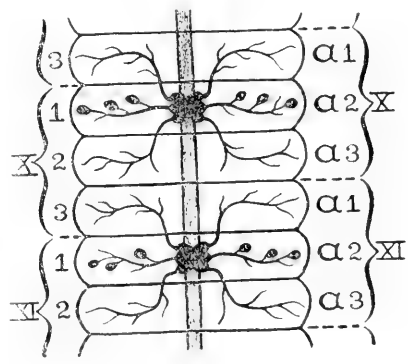


Fig. 2

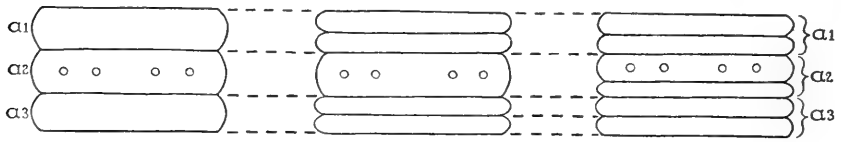
Not only does the number of annuli vary in the different species, while the number of somites is constant, as has already been stated, but the number of annuli in different somites of any given species varies. The anterior and posterior somites always have a smaller number of annuli than the somites of the middle region of the body. The typical number of annuli to a somite of any species is determind by the number in the somites of the middle region of the body. The annuli of a somite may also be equal or unequal in size. Frequently some annuli are only partially divided, and in some species certain annuli are always divided only on the dorsal or ventral side.

With regard to the annulation nearly all of the leeches can be

placed in two groups, one having three primary annuli and one five primary annuli in a typical somite.

The differences in the number of annuli and the modifications of them in the anterior and posterior somites of the leeches of Minnesota are clearly and fully presented in the systematic portion of this report. It may be well, however, to note that in all leeches several of the posterior somites (six or seven) are fusd to form the attaching sucker and the number of annuli is more or less reduced in the anterior somites.

More precise and accurate descriptions of the various species and a more satisfactory identification of each species are made possible by numbering the somites and annuli of each somite from the anterior end back. The somites are now generally designated with the Roman numerals and the annuli with the Arabic. A few examples will make this clearer than can a detaild description. A structure or marking on the first annulus of the twelfth somite would be located thus,—XII a1; something on the boundary line between the first annulus and the second of the same somite, thus, XII a1/a2; and something between the twelfth and the thirteenth, thus, XII/XIII. To indicate the relation of the secondary to the primary annuli the letters a, b, c, &c are used, a indicating a primary annulus; b, a secondary annulus and c, a tertiary annulus. The following diagram, Fig. 3, illustrates the derivation of a typical somite of five annuli and a typical somite of six annuli from one of three annuli.



Three annuli to a typical somite as in Glossiphonia.

Five annuli to a typical somite as in Macrobdella.

Six annuli to a typical somite as in Actinobdella.

Fig. 3.

The following diagram, Fig. 4, illustrates how annuli become divided into two, four or six annuli and how a somite of four or twelve or fourteen annuli may be derivd from a somite of three annuli.

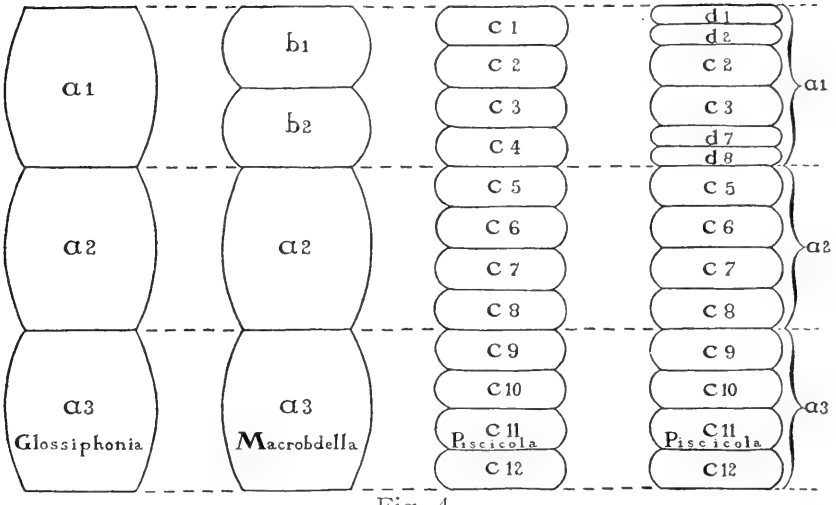


Fig. 4.

If *c2* and *c3* in the above diagram had also been divided, *a1* would be represented by eight annuli. The diagram represents the annulation of typical somites of the genera selected excepting in the case of *Macrobdella*. The typical somite of *Macrobdella* is quinquiannulate, *a3* being divided into *b5* and *b6*. The diagram represents somite VIII of *Macrobdella decora*.

Figures four and five present the system of notation adopted by Professor Moore to indicate the relationships of the annuli.

The leeches vary considerably in size. The smallest is about an eighth of an inch long and the largest (*Macrobdella valdiviana* of Chili) reaches a length of a foot and a half or more and a width of about one inch. The smallest Minnesota species is less than half an inch long and the largest is from seven to ten inches long and less than an inch wide.

The color markings are varied, simple and irregular in some and definit and regular in others. Some

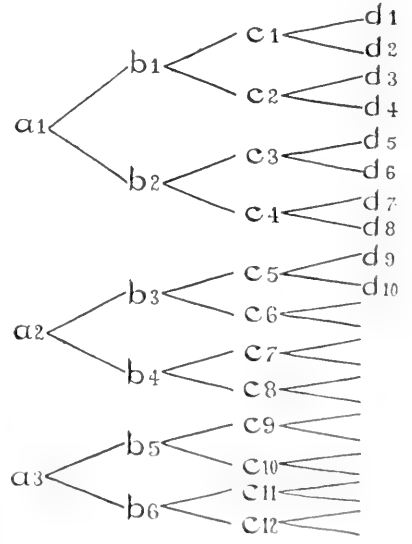


Fig. 5.

are quite dull in color and some are bright and very attractiv. A few of the color patterns are shown in the frontispiece and plate A.

In most of the leeches one to five pairs of eyes, appearing as more or less conspicuous pigment spots, are evident on the dorsal side of a few of the anterior somites. Special sense organs, cald sensillæ, can be recognizd in most leeches on the dorsal surface of one of the annuli of most of the somites.

The body has no external appendages, such as antennae or gills, excepting in a few species, not found in Minnesota; two have external gills on certain somites. But the body is always coverd with a thin, tough cuticle and more or less mucous. Some species can secrete a large quantity of mucous in a very short time.

The openings into the digestiv tract, the mouth and anus, usually are quite evident at or near the anterior and posterior ends respectively. In the region of somites XI/XII, on the mid-ventral line, there are two openings one to five annuli apart. The anterior of these is the external opening of the male reproductiv organs and the other is the external opening of the female reproductiv organs. The excretory organs open to the exterior thru inconspicuous pores on the ventral side of the somites containing them.

When a leech is cut in two the body appears to be practically a solid mass of tissue, the only conspicuous cavities being those of the digestiv tract and some other organs. The digestiv tract and other internal organs do not appear to lie in a distinct cavity as, for example, do the intestin and some other organs of the chicken or the frog. The body wall of the leech can be removd so as to leave a compact mass of supporting tissue and embedded organs, the whole presenting the general outline of the intact leech. In other words, the space between the body wall and internal organs and between the various organs is fild in with supporting tissue and a characteristic vascular tissue. Consequently, in order to get a view of the internal organs, this tissue must be carefully dissected away.

In Plate B are reproduced the fotografs of three successiv stages of the dissection of one of our large leeches. In figure 1 only the body wall has been loosend and pind out. The figure shows that the supporting and vascular tissues so completely fill the space between the various internal organs that none of the organs are very evident.

In the second stage of the dissection, shown in figure 2, the

posterior third of the digestiv tract and the supporting and vascular tissues of the posterior half of the body have been removd, thus exposing part of the digestiv tract, part of the ventral nerve cord and part of the reproductiv and excretory organs.

In the third stage, shown in figure 3, the supporting tissues and all of the digestiv tract have been removd, thus exposing the reproductiv organs, the excretory organs and the central nervous system.

The longitudinal muscles of the body wall are plainly seen in each of the three figures.

INTERNAL ANATOMY

Digestive Tract.

The digestiv tract is a more or less highly differentiated tube extending from one end of the body to the other. In most of the Minnesota leeches several distinct regions can be easily recognizd in it. But there is no uniformity in the differentiation nor in the names applied to the several regions by the various writers.

The Mouth

is on the ventral surface at the anterior end in the center of a more or less well developt sucker. In one group of leeches, cald the *Gnathobdellidae,* it is provided with three "jaws" that radiate from a common point with an angle of about thirty degrees between the middle jaw and each of the outer of the trio. The free edge of each jaw is curvd and coverd with a horny (chitinous) band that is notcht like a saw. When these jaws are workt back and forth on the skin of the host by the special muscles attacht to them they cut a ragged wound in the skin, which bleeds much more freely than would a single clean cut. The mouth opens into a short portion cald the

Farynx or Esofagus.

This is a muscular region which by the action of its muscles can create a strong suction thru the mouth. In one group of leeches, cald the *Rhyncobdellidae,* it can be protruded and is often spoken of as the proboscis. In the true bloodsuckers this region has opening into it a large number of unicellular glands cald salivary glands. They are located mainly in the two or three somites immediately in front of the anterior reproductiv opening. Hemingway has also describd a multicellular gland he calls the esofageal gland that opens into this region thru a cellular duct. For the full account see page 49. These glands produce a secretion which prevents the coagulation of the blood suckt from the host. The esofagus opens into the largest portion of the digestiv tract, cald

Stomach or Crop.

In the true bloodsuckers this region has from two to fourteen or more lateral diverticula or pouches technically cald gastric ceca. As a rule there is one pair of these ceca to a somite in the region of the stomach but in some cases there are two pairs to a somite. They are side pockets which serve as reservoirs for the ingested blood. When they are full the leech may leave the host and seek some secluded place where the digestion of the bountiful meal may be continued in peace. The blood does not clot in this region owing to the addition of the secretion from the glands noted above. When all the blood has been digested the leech will actively seek a host for a new supply. The adults of some species may store enough blood in this region to last for several months. The medicinal leech has been known to make one meal last for more than nine months. Generally there are no digestiv or gastric ceca in the leeches which do not suck blood. In this group the digestiv tract is a straight tube markt into the several regions by differences in size and general structure. The stomach or crop opens into a narrower portion cald the

Intestin

In the true bloodsuckers this also may have several pairs of lateral diverticula, cald intestinal ceca. When the blood enters this region of the digestiv tract it becomes rapidly changd in color and composition. This indicates that activ digestion takes place in this region. A short terminal portion of the intestin is sometimes so modified that it can be recognizd as a distinct region. When recognizable it is cald the rectum. The intestin or rectum opens to the exterior thru a small inconspicuous opening cald the

Anus.

The anus is on the mid-dorsal line usually on or near the boundary between the body and the posterior sucker.

The general anatomical features briefly noted above are represented in figure 4 of plate C and in part in plate A.

Circulatory System.

The blood vascular or circulatory system in general consists of several longitudinal vessels (dorsal, ventral and lateral), connecting branches in each somite, vessels to the nefridia and other organs,

and socald sinuses, some of which, if not all, represent portions of a true body cavity. Portions of this system have contractile walls. The blood is kept in circulation by the more or less regular pulsations of these vessels and the irregular contractions of the very muscular body.

Respiratory System.

None of the leeches found in Minnesota have any special organs of respiration. That function is performd almost wholly by the skin. Two marine genera, *Branchellion* and *Ozobranchus,* have gills on certain somites.

The Excretory System.

The excretory system consists of a series of more or less highly differentiated tubes cald nefridia. Each somite, excepting a few at the anterior end and a few at the posterior end, contains a pair of these nefridia, one on each side. Typically the nefridium consists of a funnel-shapt "mouth" that communicates with a small space representing the body cavity, a glandular portion well supplied with blood-vessels and a non-glandular, bladder-like reservoir which opens to the exterior thru a small pore (the nefridiopore) on the ventral side of the body. When a living leech is wipd dry on the ventral side and is then carefully comprest laterally, small drops of the secretion of the comprest nefridia may be made to appear at the nefridiopore and make evident the position of the pore.

The Nervous System.

The central nervous system is essentially a series of paird ganglia (collections of nerve cells and nerve fibers) connected by a double nerve. In this chain we recognize a pair of small, somewhat pearshapt ganglia near the mouth on the dorsal side of the farynx or esofagus. They are connected with each other at their larger ends and are cald the brain or supra-esofageal ganglia. The smaller end of each ganglion is continued into a nerve that passes around the farynx to meet the one from the other side beneath the farynx on the midventral line in a paird ganglion often cald the sub-esofageal ganglion.

From the sub-esofageal ganglion the double nerve extends along the midventral line of the body wall, immediately under the digestive tract, to the posterior end, connecting a series of ganglia,

one ganglion for each somite. This chain of ganglia and connecting nerve fibers are collectively cald the ventral nerve cord. From each ganglion three pairs of lateral nerves radiate out to the various parts of the somite. One pair of these nerves always goes to certain sense organs of the somite and the others go to other definit regions and organs of the somite.

For a more detaild account of the anatomy of the nervous system see Hemingway's account of the anatomy of the nervous system of *Placobdella pediculata,* page 40.

Reproductiv System.

The leeches are hermafroditic. That is, both the male and the female reproductiv organs are present in each individual. But the two sets of organs are so related in the leech that the eggs of one individual are fertilizd by the spermatozoa of another.

The male reproductiv organs consist of a series of pairs of spermaries or testes close to the nefridia in certain somites. The number varies from five to eleven pairs in the different species. The series on each side is connected by a common duct, cald the vas deferens, which opens into a muscular tube in the neighborhood of somite XI. The terminal portion of the common duct of the two vasa deferentia is sometimes cald the penis. It can be protruded thru the male reproductiv pore on the mid-ventral line near to or on somite XII. The position is constant for a given species but varies in different species.

The essential female organs consist of only a single pair of ovaries. The ovaries usually lie in somite XI and the female reproductiv opening is on the mid-ventral line one to five annuli behind the male opening. For a detaild account of the essential and accessory female organs in one species see Hemingway's account of *Placobdella pediculata,* pages 47 to 49.

Specific anatomical differences are noted in Part III of this report.

In some species fertilization may be accomplisht in a peculiar way. The spermatozoa are collected in small packets, cald spermatofores. These spermatofores are attacht to any part of the body of another leech and the spermatozoa escape thru the body wall of the leech into the underlying connective tissue and thence work their way to the ova near the uterus, where fertilization takes place. In others fertilization takes place in the uterus (or in capsules con-

taining ova, spermatozoa and some albuminous material) by spermatozoa introduced into the uterus directly thru the external opening.

Some leeches, like *Nephelis,* lay a few eggs at a time in small tough capsules that the leech attaches to the submergd parts of water plants, stones &c. Others, like *Hæmopis,* enclose a few eggs in egg-shapt capsules or coccoons that may be half an inch or more in length. These coccoons are deposited in masses of decaying vegetation, such as the submergd portions of muskrat houses and the accumulation of ded roots, leaves and water plants near the shore or on the bottom of the lakes. Others, like *Placobdella rugosa,* carry the eggs and young attacht to the ventral surface of the body until the young are able to move about actively and find a host for a meal of blood. In these cases the eggs are laid in small spherical clusters, each mass surrounded by a delicate membrane of a mucous-like substance secreted by skin glands. A number of such groups of eggs are somewhat loosely held together and are attacht to the ventral surface of the parent by a substance similar to the membrane around each spherical mass of eggs. When thus burdend with eggs or young the leech does not travel about very much but stays in some protected place and by undulatory movements of the body keeps the collection of eggs or young well aerated until the young are able to shift for themselves. If the egg masses become dislodgd the parent will make efforts to collect them and again attach them to her body. Several *Placobdella parasiticas* with young in various stages of development are shown in Plate A.

The development and anatomy of the leeches in general and certain special structures of two or three annulata that appear to be on the border-line between the leeches and other groups of annulata indicate that the leeches are more closely related to the group of earthworms than to any other group of the annulata.

PLATES A AND B
AND
EXPLANATIONS

PART I

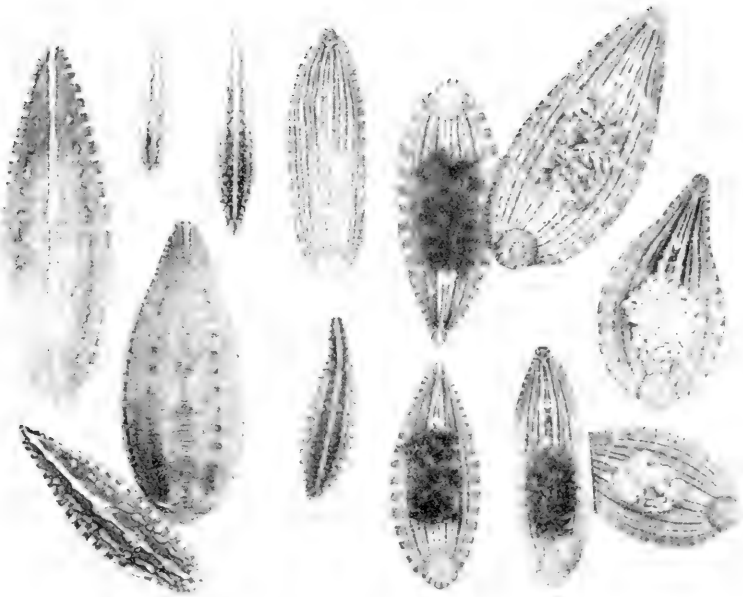
Explanation of Plate A

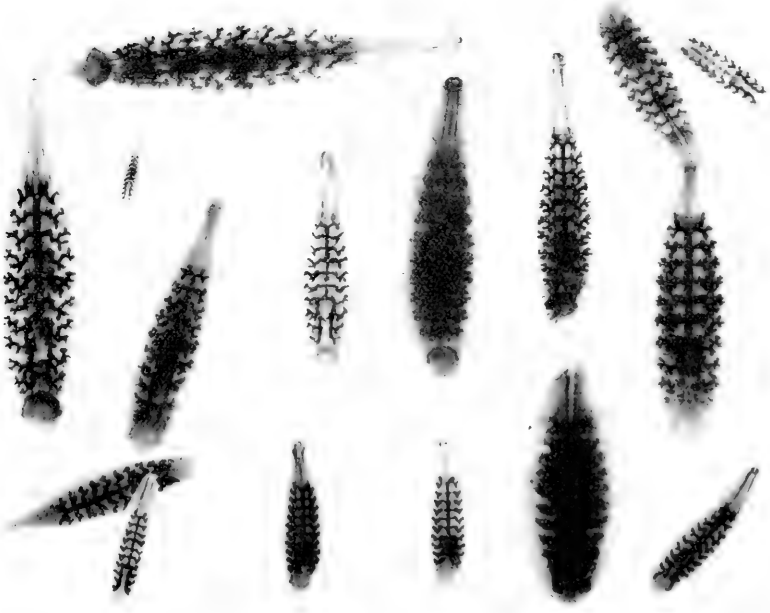
Reproductions of fotografs of living leeches.

Several of the upper group show the color patterns of some of the Glossiphonidae. The six figures to the right of the group show young leeches in different stages of development attacht to the ventral surface of the parents.

The lower group of figures shows the gastric and intestinal ceca more or less fild with blood. The delicate edge of the leech body is not evident in all cases.

The species represented are *Placobdella parasitica* and *P. rugosa*.





Explanation of Plate B

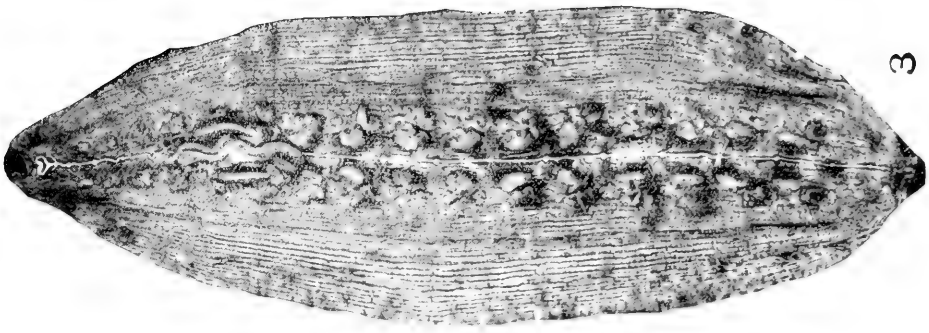
Reproduction of fotografs of Hæmopis grandis in three stages of dissection.

Fig. 1. Represents the leech with the body wall cut along the mid-dorsal line and pind out on each side.

Fig. 2. Represents the same leech with the supporting and vascular tissue of the posterior half and all of the intestin removd. A small portion of the dorsal wall of that part of the digestiv tract shown is cut away.

Fig. 3. Represents the same leech with all of the digestiv tract and surrounding supporting and vascular tissue removd. The "brain", ventral nerve cord, reproductiv and excretory organs are easily recognizd.

The logitudinal muscles of the body wall are evident in all the figures.



3

2

1

PART II

THE ANATOMY
OF
PLACOBDELLA PEDICULATA

BY
ERNEST E. HEMMINGWAY

INTRODUCTION

In the summer of 1899, while at Lake Pepin superintending the zoological work of the Geological and Natural History Survey of Minnesota, Professor Nachtrieb found that some of the sheepshead (Aplodinotus grunniens) which were being seined from the lake in large numbers by the local fishermen, had a large parasitic leech fastened to the isthmus or shoulder under the gill cover. Three of these leeches were collected at that time, with portions of the fish, showing the place and manner of attachment. One of these specimens was later sent to Professor J. Percy Moore who found it to be a new species of *Placobdella* and named it *P. pediculata*. All the specimens originally collected were adults, gorged with blood, and greatly modified in form from the usual Placobdella types by their close parasitic habit; so that, in some parts, annulation and many other external features had been entirely obliterated. It was seen at once that to determine these features, younger and better preserved material must be obtained, so during the first part of September 1903, I spent several days with the fishermen around the head of Lake Pepin examining fish for these leeches. During this time I examined many hundreds of fish and succeeded in obtaining three small specimens, none of which were over a centimetre in length.

Methods.

The leeches were removed from their hosts as soon as found and placed in carbonated water (I used the ordinary bottled "pop" for this purpose) in which they soon became fully extended and stupefied. After they had become perfectly quiet (in five to ten minutes) they were transferred from the carbonated water to Gilson's mercuro-nitric mixture, in which they were left for an hour, and then put into 80% alcohol and treated with iodine in the usual way. This method left all well extended and in excellent condition for study. One was stained in bulk in Mayer's Paracarmine, imbedded in paraffin, cut in transverse series 20/1000 mm. thick, and mounted without further staining. The second was stained in bulk in Mayer's Paracarmine, imbedded in paraffin, cut in sagittal series 5/1000 mm. thick, and counterstained with Lyons blue before

mounting. The third was cleared in cedar oil and examined as a transparent object. Both external and internal features, as far as they could be made out, were drawn with the camera lucida. This specimen was then imbedded in paraffin, cut in transverse series 5/1000 mm. thick and stained with Ehrlich-Biondi stain. The nervous system, (Figs. 17 to 22.), reproductive system, (Figs. 11 to 14), and the oesophageal gland, were worked out by the Born Reconstruction Method from series three, and the wax models thus made were checked up with similar models made from sagittal series two. Wax models made from these two series were found to differ only in minor details, due to slight anatomical variations and distortions which one would expect to find in any two individuals of the same species.

While the method which I have used is essentially the Born method, I have modified it in several ways. My drawings for this purpose were all made with a soft Faber pencil, on unsized paper, from the third series noted above. But instead of drawing every section, only alternate sections were drawn, and in some cases only every fourth section was drawn, the sections between being used to show the relations of parts which had changed too much to have their relations perfectly clear in the drawn sections. The result attained is the same as though the series had been cut two or four times as thick, with the added advantage that one is able to trace out minute changes which would not appear in the thicker series. The thickness of the wax plate was made to correspond with the magnification and the distance between the sections as by Born. For the models of the central nervous system, I took alternate sections and drew them with a magnification of 400 diameters, so the wax plates required were 4 mm. thick.

In making the wax plates I used a method which is quite different from that of Born, and one which I think is in many ways superior. I first found by mathematical calculation the amount of melted wax which it would take to produce a plate 1 mm. thick in pans of a convenient size, and then procured a ladle which, when filled, would hold exactly that amount. I then got ready a large dish of melted wax and a quantity of hot water. The pans were, one by one, filled nearly full of hot water and, according to the thickness of the plate wanted, one, two, three or four of the ladles full of hot wax were poured upon the surface of the water and spread over it evenly with a hot spatula. A little extra wax was always added

so that the plates would be slightly thicker than they were finally wanted. As the wax plate congealed, it was cut free from the edges of the pan to prevent its cracking; and when the plates were sufficiently hard, they were lifted out by one edge and laid upon some flat surface until cold, then they were cut into the sizes required. By having several pans of the required size, a large number of plates can be made in a short time and kept on hand ready for use.

Two metal strips of the required thickness, as used by Born, were then placed a short distance apart on a piece of plate-glass. Between these strips was laid a sheet of tissue paper, and on this the wax plate of the right size and thickness; and on top of the wax plate the sheet of paper with the camera-lucida drawing was placed, drawing side up. The surface was then brushed over with a liberal amount of turpentine, and a hot roller, long enough for both ends to rest upon the metal strips was passed over it. The roller which I used was of hollow brass, filled with hot water, which was easily kept at the proper temperature by means of a Bunsen burner. As the temperature of the roller was always slightly above the melting point of the wax, the superfluous wax was pressed out at the edges leaving the plate of the exact thickness required. The drawings were then cut out, superimposed, and the edges trimmed off in the usual manner.

PLACOBDELLA PEDICULATA n. sp.

Habits.

This leech appears to be a true fish parasite and is found in the gill chamber of the common sheepshead, Aplodinotus grunniens, with the posterior sucker deeply imbedded in the side of the isthmus. In the case of young leeches which have not been long attached, the hole made by the posterior sucker is comparatively shallow, being a mere external depression in the inflamed tissue which surrounds it. As the attachment continues the inflamed tissues of the fish grow up like a collar and close in around the leech's body in front of the sucker. This closing up of the inflamed collar presses upon the body of the leech, narrows it to a mere peduncle, and incidentally crowds the sucker down into the tissues of the fish so that in time this depression will reach into the underlying muscles to a depth of half an inch or more, and have an opening of about a quarter (or less) of an inch in diameter. The bottom of the

depression has a much larger diameter. A look at Plate C will help toward a clear conception.

Pl. C, Fig. 5, shows the holes in the isthmus of a fish from which the leeches have been removed, and Fig. 6 represents a longitudinal section of one of these holes. The surrounding tissue of the fish rolls up to form an inflamed collar about the attenuated peduncle of the leech. These leeches are capable of becoming greatly contracted and when one is disturbed it draws back until it appears as a mere brownish pyriform knob which entirely covers the place of attachment. This burying of the posterior segments in the tissues of the host has brought about an interesting structural change so that we find the anal opening shifted forward to a position between somites XXIII and XXIV instead of between somites XXVII and XXVIII as in other members of this genus. It is noticeable that, while the young leeches whose posterior portions are not yet deeply imbedded, have the characteristic position of the anus, XXIII/XXIV, the outline of the posterior part of the body is still a regular curve (Fig. 4), showing none of the pedicular characteristics so pronounced in the older individuals. The posterior sucker, however, is very strongly developed even in those not more than a centimetre long.

Practically nothing is known of this leech apart from its host, but it seems possible that a part of its existence may be spent elsewhere. During September 1903, I examined several thousand fish of this species from Lake Pepin and found only three isolated leeches, each about a centimetre in length. The posterior sucker, while imbedded in the tissue, was not sunk in deeply and so had not produced the characteristic peduncle. They were evidently young ones which had recently attached themselves to their hosts and were gradually sinking the posterior sucker into the flesh. As full grown specimens, deeply attached, were found in the same locality during August of 1899, at least some of the adults must remain with their hosts during the summer and probably throughout the year.

DESCRIPTION. *

Plate C, Figs. 1, 2, 3 and 4.

Like *Placobdella parasitica* and *P. rugosa* this is a species of large size, thongh not quite equaling the largest examples of the forms mentioned. It is more than usually contractile and therefore difficult to preserve in suitable condition for study. The very characteristic pyriform outline and strongly convex dorsum are evident from the figures, but the most striking peculiarity is the attenuation of the posterior somites to form a narrow pedicle just in front of the caudal sucker, which consequently stands out freely exposed behind the body in a most characteristic manner. The oral sucker has the same structure as in *P. parasitica.*

No trace of cutaneous papillae can be detected, the skin being perfectly smooth, and the segmental sensillae and scattered sense organs are very indistinct. Eyes are very difficult to detect in the mature animals, but appear as small pigment masses at III/IV in the young. The annulation is essentially like that of *P. parasitica* excepting the caudal peduncle and the generally simpler structure of the corresponding somites of *P. parasitica.*

Somites I and II contain each but a single annulus. Somites III and IV are bi-annulate and V is bi-annulate dorsally but ventrally the furrow fades away medially; VI is tri-annulate above, but the furrow a1/a2 is incomplete below. Somites VII to XXIV are tri-annulate but the furrow a1/a2 is incomplete medially on the ventral side of both VII and VIII and in most of the succeeding somites is less marked than either a2/a3 or the inter-segmental furrows. In the anterior somites, and, to a less degree, in the posterior, a3 is slightly longer than a1 or a2. The annulation of the post-anal somites, constituting the caudal peduncle, is irregular and somewhat puzzling on the older specimens, but is fairly distinct on the younger ones. Somite XXIV, which immediately succeeds the anus, is tir-annulate. Somites XXV, XXVI and XXVII are all bi-annulate.

*This description is based upon both young, and large, mature specimens gorged with blood. In view of unavoidable delay in the publication of Professor Nachtrieb's projected report on the Leeches of Minnesota, Professor Moore kindly consented to the free use of his description embodied in the systematic portion of this report. I have retained the specific name suggested by Moore, though his description, being based upon a single large, gorged and much contracted specimen was of necessity somewhat incomplete.

The original description was published in The American Naturalist, Vol. XLII, August, 1908.

but a1 of Somite XXV is partially divided and a1 of both XXVI and XXVII is larger than a2. Neither annulus of XXVII is complete, a1 reaching only to the sides of the body and a2 not so far. The disc is composed of somites XXVIII to XXXIV. Fig. 4 represents the arrangement of the furrows in a young animal. Somite XXIV is the last segment of the body proper and its posterior boundary forms in contracted specimens a fold which envelopes the contiguous portion of the narrowed peduncle. The latter continues to narrow to the sucker, to the middle portion of which it is strongly attached for rather more than the posterior half. The posterior sucker is large, circular and directed strongly ventrad. The nephridiopores are in the sensory annuli of somites VIII to XI, and XIII to XXIII and are placed similarly to those of *P. parasitica.*

The mouth is very small and situated far forward near the anterior rim of the sucker in somite II. As in related species the proboscis is slender, and the crop provided with seven pairs of large caeca reaching nearly to the margins of the body. The caeca, however, are less deeply and finely divided than in *P. parasitica,* each of the first six pairs exhibiting only two or three rather short lobes. The intestine reaches to the posterior part of somite XXIV or even beyond and then bends abruptly forward toward the dorsum as an extremely narrow rectum reaching to the minute anus situated at XXIII/XXIV. The forward curvature of the rectum and the anterior position of the anus are unique features in the family. The salivary glands are widely scattered through the anterior two thirds of the body. On either side of the oesophagus, in somites X and XI, lie a pair of compact oesophageal glands which join the oesophagus by a short duct in somite XI.

The reproductive organs are essentially similar to *P. parasitica.* The male and female external orifices are situated at XI/XII and XIIa2/a3 respectively. Six pairs of testes are crowded between the bases of the gastric caeca. The large sperm sack and ejaculatory duct of the vas deferens form a compact snarl in somite XII in the immediate neighborhood of the atrium.

THE ANATOMY OF THE CENTRAL NERVOUS SYSTEM OF LEECHES.

A brief Historical Sketch.

The first writer to describe in any way the central nervous system of the leech was Poupart who, in 1697, spoke of a knotted

nerve cord which extends from the mouth to the posterior end. With the exception of Haller who claimed that the leech had no nervous system, no further mention is to be found until 1791 when it was again described by Bibiena. In 1795 Mangili gave the correct number of ventral ganglia with a good illustration of the nerve cord. The supra-oesophageal ganglion, however, seems not to have been known to him. In 1809 Cuvier described correctly the oesophageal collar and its connection with the sub-oesophageal mass; he gave the whole number of ganglia as twenty-three but did not distinguish the posterior ganglion from the others. Like other early writers he discribed the cord as single. Spix, in 1813, was the first to discover the double nature of the nerve cord. He also gave the correct number of nerves arising from the ventral ganglia, but found only two pairs for the anterior ganglion; the supra-oesophageal ganglion was not known to him.

Up to this time the surrounding ventral vessel had been considered as part of the nerve cord, but Johnson, in 1816, described it as a ventral vessel. Bojanus, in his Anatomy of the Leeches, in 1817, speaks of the entire independence of the nerve cord and the blood system; and Joh. Miller, '28, speaks of the ventral vessel as the "eigene schwartze Haut des Markstranges." The monograph of Moquin-Tandon, '27, added very little that was new to the knowledge of the nervous system. He found that, toward either end of the nerve cord, the ganglia became crowded nearer together, that the two end ganglia were larger than the others, and that the caudal ganglion was made up of seven or nine ventral ganglia. He concluded from this that the caudal ganglion was not yet completely formed. Weber, '28, declared the last ganglion to be a second brain made up of seven knotted swellings. He writes, "Ich zähle wie Bojanus, das Gehirn mit gerechnet, 22 Ganglien des Knoten stranges. Aber des im Saugnapfe des Schwanzes vorhandenen Ganglienstranges finde ich aus 7 verschmolzenen Knoten bestehend und also einem zweiten Gehirne ähnlich . . . . Die 2 Fäden des Ganglienstranges welche die Knoten desselben unter einander verbinden, verlaufen an den dem Saugnapfe des Schwanzes nahe liegenden Knoten getrennt von einander. An den 7 verschmolzenen Knoten dagegen, welche in der Mittelline des Saugnapfes des Schwanzes befindlich sind, vereinigen sie sich. Jeden von den 7 verschmolzenen Knoten hat übrigens Aehnlichkeit mit einem einzelnen Knoten des Ganglienstranges."

Brandt, '33, found three small ganglia lying behind the jaws and a nerve running along the digestive tract which he declared to be the sympathetic nervous system.

Up to this time practically all the work done on the nervous system had been by surface dissection; only the external appearance, after the outer tissues had been removed, being considered. The work on the inner structure then began and we find Ehrenberg, Valentine, Helmholtz, Hannover, Will Bruch, Leydig, Quatrefages, Faivre, and Walter contributing to the microscopic anatomy of leeches.

After Newport had discovered, between the two connecting commissures in some of the arthropods, a third smaller commissure, Faivre, '56, described a similar nerve, since known as the Nerve of Faivre, for *Hirudo medicinalis*. According to his account, this third commissure ran from one ganglion to the next, between the two principal commissures, in many places fusing with these larger cords. He made the number of nerves springing from the supraoesophageal mass to be four, from the sub-oesophageal three, and from the posterior at least seven. Faivre also described the Leydig's cells which had been described by Leydig in 1849. He found five ganglia in the head which he considered to be sympathetic ganglia, but found no nerve connecting them with each other, or with the central nervous system, or with the visceral nerve.

Leydig, '49, was the first to understand the follicular nature of the ganglia and was also the first to describe the cells (Leydig's cells) lying between the ganglionic nerves. In "Vom Bau des Thiereschen Körpers" '64, he describes the head ganglia and the sympatheticus, and thinks it probable that the sympathetic system is joined with the central nervous system either through direct connection with the brain, or through the Leydig's cells, or perhaps by means of the central nerve of Faivre.

Herman, '75, described the sympathetic system of *Hirudo medicinalis* and found both the head ganglia and the gastric nerve, but did not find any connection between them. He wrote, "auch ich habe nie einen Zusammenhang des Sympatheticus mit den betreffenden Ganglien oder andern Abschnitten der Bauchganglienkette gefunden, und halte, nach ihrem äusseren und inneren Bau dieses accessorischen Gebildes, theils für integrirende Bestandtheile des Gehirns, theils stelle ich sie in das Gebiet des IV. Gehirnnerven." When we examine his figure, however, we find that he has figured ten pairs of

nerves coming from the brain and that these include several branches of the anterior sympathetic nerve, so his IV brain nerve is in reality a branch of the anterior sympathetic nerve coming from the oesophageal commissure at the base of nerve II. From his description it would seem that he found both parts of the sympathetic system attached to the brain at the base of the second somatic nerve although that was not his interpretation. Herman also divided the anterior nerve packet of the ventral ganglia into "vordere ventrale" and "mittlere ventrale" making the number of packets seven instead of six.

Gratiolet, '62, pointed out that the annulation had a definite relation to the segmentation and made of each ventral ganglion the brain, situated in the first annulus, of one of the elementary zooids which go to make up the leech body. Toward the ends the zooids are more closely crowded together and so the individual annulation becomes indistinct or lost. Whitman, '84, made segmentation depend wholly upon the internal organization, annulation being no criterion to follow. Born, '84, based the number of somites upon the number of ganglia, but did not count the number of ganglia correctly. SaintLoup, '85, would go a step further than Gratiolet and make the leech a colony of annulates bearing a relation to each other similar to the relation of the trematodes which go to make up the Tenia series. Apathy, '88, saw no ground for such a colony theory, but found definite septa separating the body somites (the presence of which had been denied by Born, '84) and a portion of the coelomic cavity and a ganglion in each somite.

Whitman, '92, proved that in *Clepsine*, the whole body is made up of a series of true segments, each represented by one of the separate or fused ganglia of the nerve cord. He says, "The metameres of Clepsine show in all the important details of their external features and internal organization that they represent morphologically individuals, which have undergone internal integration by which their individualities have been merged in one complex individuality. Each metamere has its nerve-center composed of like elements, its nerves essentially identical in number, origin and distribution; and its external sense organs similar in structure, position and function." Whitman was the first investigator to work out the relation of annulation to segmentation, in the anterior and posterior regions, the morphological value of the supra-oesophageal ganglion, and the relations between ganglia and somites. He, however, made

the sensory annulus the first annulus of the body somite so that his neuromere did not correspond with the body metamere.

Bristol, '98, worked out the metamerism similarly for *Nephelis*, and, in addition, investigated the sympathetic system. He found the sympathetic system connecting with the central nervous system at the collar near nerve roots I and II and forming a nerve circle in front of the collar, with six capsules containing nerve cells, and a plexus over the wall of the alimentary tract. In the work of Bristol as well as the work of Whitman, the sensory annulus is taken as the first ring of the somite. Castle, '00, and Moore, '00, working by entirely independent methods, and without knowledge of each other's work, came to the same conclusion with respect to the annulation of the somite, viz.—that the sensory annulus is not the first annulus of the somite, but the middle one in both the three ring and five ring types. This brings the neuromere and the body somite into harmony and seems to be supported by all conditions. Livanow, '03, has worked out the innervation of the body somite for both the three and the five ringed types much more elaborately than they have heretofore been studied, and endorses the view of Castle and Moore.

In this review of the work done upon the anatomy of the central nervous system of the leech I have omitted such work as Apathy, '97, and Havet, '00, and Retzius, '91, which are of a purely histological or cytological character. Nor have I attempted to review the publications of all those who have done valuable work upon the outer form of the nervous system. Much of this work has been of a substantiating character and while these writers have added many minor details which are of value, they have made no decided advance beyond their predecessors. Some of the works referred to I have been unable to procure and so have been obliged to depend upon the quotations of other authors who were more fortunate than I and who have been able to review them first hand.

Central Nervous System of Placobdella pediculata.

(Pl. E, Figs. 17 to 22.)

The central nervous system may be divided into a cephalic portion, a trunk portion, and a caudal portion. The anterior part consists of the supra-oesophageal mass, the oesophageal collar, and the sub-oesophageal mass. The trunk portion consists of a ventral

nerve chain of ganglia, each connected with the ganglion preceding and with the ganglion following by two large lateral commissures and a third, smaller, central commissure, the so called Nerve of Faivre. The caudal portion is the posterior ganglionic mass, situated in the anterior side of the posterior sucker.

The Ventral Nerve Chain.

The ventral nerve chain is made up of twenty-one somatic ganglia with their connecting commissures. Throughout the middle portion of the body these ganglia are about equal distances apart, but toward the ends they are crowded closer together. The last three ganglia of the chain are especially close together but are separated from the posterior ganglion by a much longer space, probably due to the pressure exerted around this region by the tissues of the host. The first central ganglion is closely approximated to the sub-oesophageal mass and the fifth and sixth (ganglia XI and XII) are closer together than the others near them.

The typical ventral ganglion, which may be taken as the unit of structure of the central nervous system, consists primarily of a fibrous portion and a cellular portion. The fibrous portion is made up largely of nerve fibres entering from the connecting commissures, the somatic nerves, and the six cell packets. Fibres continuing through the ganglion from the lateral commissures form two lateral fibre tracts and the fibres crossing from one side to the other form two transverse fibre tracts, one before and one behind the center of the ganglion. Among the fibres are to be found occasional leucocytes and two large glia cells (mediane Sternzellen of Apathy, '97). These glia cells are medially situated beneath the two transverse fibre tracts, one anterior and one posterior to the centre of the ganglion. In a few cases I have found the anterior cell divided so that there were three median glia cells in the ganglion instead of two. Herman, '75, described these cells as "mediane Ganglienzellen", Retzius, '91, as "kolossale Ganglionzellen" and "Nervenzellen". Apathy, '97, was the first to describe them unmistakably as glia cells.

The cellular portion of the ganglion consists of six cell packets, each containing nerve and glia cells, and surrounded by a regular capsule from which emerge the nerve fibres of the enclosed nerve cells. These packets occupy a definite position in each ventral ganglion, two being on each side, lateral to the central fibrous mass,

and two being on the ventral side directly underneath the median glia cells. The packets are usually ellipsoid in shape, but may be variously distorted by constricting muscle and nerve fibres, so that they are, in some cases, completely divided.

The cell packets each contain a number of unipolar nerve cells which send their fibres directly into the fibrous portion of the ganglion, and one or more large glia cells ("Stirnzellen" Apathy, '97). Each side packet contains one of these cells, sometimes centrally located, but often lying near the outer margin of the packet. This condition holds good throughout the nerve cord. The glia cells are much larger than the ganglion cells, and as the nucleus stains much more deeply with the ordinary chromatin stains, they can easily be distinguished from the other cells of the packet. In each ventral packet a pair of these glia cells are found lying side by side near the distal end of the packet. This double condition of the glia cells of the ventral packets is not unique for *P. pediculata,* but is found in at least one other *Placobdella,* viz. *P. parasitica,* however, the glia cells in the side packets are also double.

From each side of the fibrous portion of the ganglion, midway between the two lateral packets, arise the three branches of the somatic nerve; these pass backward and laterally, usually passing under the posterior lateral packet, and then to the various annuli of the somite in which the ganglion is situated.

The connecting commissures consist of two large cylindrical fibrous trunks, the lateral commissures, and a smaller central Nerve of Faivre, (Plate E. Fav. n.) which takes its origin in the ganglion between the two lateral commissures, or from one of these commissures near the ganglion. This central commissure may continue its course independently between successive ganglia, occupying a position between the lateral commissures; or it may, in places, anastomose with one of the lateral commissures. A lateral commissure, instead of always remaining a single trunk, frequently divides into two branches which, after a short distance, again unite into one cylindrical cord. In some cases all three commissures are fused, for a short distance, into one solid cord. Lying along the central axis of the commissure are two or more large spindle-shaped intercommissural cells. The normal number of these cells seems to be two, one lying near each end of the commissure; but in many cases one or both of these cells have divided, forming three, four, and, in some cases, up to eight cells scattered along the whole

length of the commissure. Lavinow, '03, finds this same double condition of the intercommissural cells in *Protoclepsis tessellata,* and thinks there is some relation between the doubling of these cells and the binucleate condition of the muscle cells. As nearly all the muscle cells in *P. pediculata* are also binucleate, the same relation would seem to exist here. Appearances would seem to indicate that amitotic division is the prevailing method for all these nuclei. Lavinow, '92, would make the binucleate condition of the muscle cells and the presence of two intercommissural cells, characteristic for a new genus, *Protoclepsis,* which would separate it from *Hemiclepsis,* on the one hand, and the *Glossiphonidae* (*Glossiphonia, Placobdella* and *Haementeria*) on the other. The possession of both of these characteristics by at least two species of *Placobdella,* viz. *P. pediculata,* and *P. parasitica,* would indicate that there is a much closer relationship between the genera *Protoclepsis* and *Placobdella* than Lavinow imagined.

The Anterior Ganglionic Mass.

(Pl. E, Figs. 17, 18 and 19.)

In *P. pediculata* there are no sharply defined supra- and suboesophageal ganglia. The cell packets belonging to the suboesophageal ganglion of such leeches as *C. hollensis* Whitman extend in this species far around toward the dorsal side of the oesophagus, while the packets of the supra-oesophageal ganglion extend ventrad beyond the median line, so that some packets belonging to the former are much farther dorsal than some packets belonging to the latter. The anterior ganglionic mass consists, as Whitman, '92, has shown for *C. hollensis,* of six closely joined neuromeres, each having the parts equivalent to one of the ganglia of the ventral chain. The commissures are here shortened almost to complete disappearance, leaving the ganglia so closely approximated that only a small canal, across which runs the central Nerve of Faivre, remains between the adjacent fibre masses. Above each packet is to be found the usual central glia cell.

The eight ventral packets of neuromeres III, IV, V, and VI are arranged in a median ventral row, so closely crowded together that each body of the row, with the exception of the two at the ends which are about as long as wide, is two or three times as wide as long. The ventral packets of somite II are somewhat smaller and

are arranged side by side at the head of this row. The side packets are not so regularly arranged. The fourteen side packets belonging to somites VI, V, IV, and the posterior half of III, are arranged in two irregular rows at either side of the fibrous mass. The anterior packets of somites IV and V are shoved closer together and dorsad, while the posterior packet of somite IV is crowded ventrad. The lateral packets of somite II and the anterior lateral packet of somite III lie along the posterior side of the oesophageal collar, which bends sharply dorsad from the suboesophageal portion, and extends in a wide loop around the digestive tract. An interesting variation is to be noticed in the left posterior lateral packet of somite II which has been completely divided, retaining only a common point of attachment. Partial or complete division of cell packets is rather common in different parts of the nervous system and is evidently the result of the mechanical pressure of organs which may be in contact with them. In some cases it is probably brought about by constricting muscle fibres, while in others it is clearly the result of a nerve having been crowded against the packet until it has pinched it completely in two.

The six packets of cells of somite I are situated on the anterior side of the oesophageal collar, the ventral packets having been pushed to the extreme dorsal side of the loop, while the lateral packets lie along the sides of the collar below the outer margins of these dorsal packets. The posterior pair of lateral packets of somite I are about as far ventral with respect to the oesophagus as the anterior pair of somite II are dorsal. There is, then, in this species, no distinct supraoesophageal ganglion, but a suboesophageal mass and an oesophageal collar, around which are distributed ganglionic packets belonging to the first three ganglia. The equivalent, however, of the supra-oesophageal ganglion is to be found here in the part anterior to the collar. The oesophageal commissures which go to form the collar are not the homologues of the lateral commissures of the ventral chain, but are made up of the ganglionic fibre masses of several ganglia. This state of affairs is exactly what we should expect to find if several ventral ganglia had been crowded together until the ventral commissures were practically eliminated, and then the oesophagus had been forced between the anterior two, pushing the median ventral bodies of these two ganglia with their crossing fibre masses, to the extreme dorsal and ventral sides. The position of the ganglionic parts would seem to indicate that there had been

a concentration of ganglia around a small mouth followed by a stretching of parts as the collar slipped back over the larger pharynx, as supposed by Whitman, '92.

In ganglion VI we have an arrangement similar to the typical ventral ganglion in all respects except that the packets are more closely pressed together and the somatic nerves arise nearly opposite the anterior bodies. Ganglion V is similar to ganglion VI except that the central trunk of the somatic nerves (V2) takes a dorsal course, passing across the inner anterior margin of the anterior lateral packet of ganglion V, then passing between the lateral packets of ganglion II and over the lateral dorsal margin of the oesophageal collar. Ganglion IV is similar to ganglion VI except that the somatic nerve of each side is composed of two trunks instead of three. Ganglion III differs from ganglion IV in that the anterior lateral packet is attached to the posterior side of the oesophageal collar directly above the posterior packet. The nerve of this somite takes its origin just in front of the anterior lateral packet.

Ganglion II departs widely from the typical somatic ganglion, the ventral packets being side by side at the anterior ventral side of the oesophageal collar and the lateral packets being far dorsal on the posterior side of the collar. The nerves of this somite have each been reduced to one trunk which takes its origin from the anterior side of the oesophageal collar just outside and above the ventral packet of that side. From the inside of the collar at the base of this nerve, arises the stomatogastric nerve (Plate E, st. n.) which arches toward the median line and then turns caudad along the oesophagus. This nerve arises just where we should expect the anterior "motor" trunk of the somatic nerve, but the part supplied is very different from that which we should expect the anterior branch of the somatic nerve to supply. The similarity of this nerve to the vagus nerve of vertebrates, both in origin and termination, is rather striking.

Ganglion I is very similar to ganglion II, but the ventral packets have been pushed to the dorsal side of the collar and the lateral packets have migrated to the anterior side. The nerve of somite I has only one trunk and arises from the inside of the collar a short distance above nerve II. Just outside the origin of this nerve lies the posterior lateral packet. In the collar, just above the base of each nerve of somite I, there is a large nucleus which evi-

dently belongs to the central glia cell of this somite. It will also be remembered that in the ventral ganglia each lateral packet contains only one large glia cell, while the ventral packets each have two. A further examination of the packets of somite II reveals the fact that the four packets at the sides of the collar likewise have only one glia cell, while the two dorsal packets each contain two. This must be considered as still farther and more conclusive evidence of the homology of the supraoesophageal ganglion and the ganglia of the ventral chain, and it also makes the two central packets at the dorsal side of the collar homologous with the ventral packets of the ventral ganglia. No trace of the Nerve of Faivre, which is present in the openings between all other ganglia, could be found here. It seems to have completely disappeared.

The Posterior Ganglionic Mass.

(Pl. E, Figs. 20, 21, and 22.)

Throughout the posterior portion of the body of the leech, the nerve cord runs nearly parallel to the ventral surface; but when the commissures enter the posterior sucker and become united in the posterior ganglionic mass, they bend sharply dorsad making nearly a right angle with the line of the ventral cord. The posterior mass shows unmistakable evidence of being composed of seven somatic ganglia which have been crowded together in a manner similar to those of the anterior mass. Each of the original ganglia retains its six cell packets, two central glia cells, and its pair of somatic nerves. Each nerve, however, has only two trunks instead of three as in the ganglia of the ventral chain.

In the anterior ganglion of this mass, neuromere XXVIII, the packets have retained more nearly their typical arrangement than in any of the succeeding ganglia. The two ventral packets occupy practically the same position as in the ganglia of the ventral chain, but the side packets have been crowded together so that the anterior one comes to lie nearly above the posterior and the somatic nerves arise behind the posterior lateral packets. In all succeeding ganglia the ventral packets lie side by side, making two rather irregular rows, and the ventral packets of somite XXXIV are attached close to the bases of the somatic nerves of that segment. In somites XXIX, XXX, XXXI, XXXII and XXXIII, the posterior lateral packets are attached by a narrow neck close above the bases of the

somatic nerves, while the distal end of the packet lies some distance out on the anterior (dorsal) side of the nerve. The anterior lateral packets occupy a position antero-dorsal to the posterior packets against which they are closely crowded. The left posterior lateral packet of ganglion XXIX has been completely divided by the nerve so that half comes to lie on either side of it; both parts, however, enter the common fibre tract at the same place (Pl. E, Fig. 21). The lateral packets of somite XXXIV have been crowded entirely away from their lateral position so that they have come to occupy a central position, close together upon the dorsal side of the ganglion. Along the median line of the fibrous portion of the mass is to be seen the line of openings which are the remains of the commissural openings. They are six in number, separating the seven ganglia of the mass, and in the center of each is to be seen the very short piece of the Nerve of Faivre. At either side of these openings are the usual central glia cells.

Eyes.

There is a single pair of eyes situated near together at III/IV. The pigment cup and visual cells are deeply seated and the sensory cells from the sensillae (sensilla III) are correspondingly long. I find nothing in my sections of young leeches to suggest the doubling of the eye as found by Whitman, '92, for *Clepsine hollensis*. There are a few pigment cells below sensilla II and a similar group below sensilla IV, but there is no arrangement of them which would indicate an optic cup containing visual cells.

Reproductive Organs.

(Pl. C, Figs. 3 and 4, and Pl. D, Figs. 11 to 16.)

The male genital pore, (♂, Fig. 3, Pl. C and Fig. 11, Pl. D) lies in a mid-ventral position at XI/XII. The female genital pore, (♀, Fig. 3, Pl. C and Fig. 11 and Fig. 16, Pl. D) lies two rings behind the male opening at XII *2a/3a*. There are six pairs of testes, (T. Fig. 4, Pl. C and Figs. 11 and 12, Pl. D) situated inter-segmentally from XIII/XIV to XVIII/XIX. They are nearly spherical in shape and lie in the spaces between the crop diverticula, the last pair lying behind and median to the last pair of diverticula. Owing to the pressure of the other organs they are somewhat flattened antero-posteriorly with the exception of the last pair which are larger than the others, and, as they have no diverticulum behind them, are considerably elongated.

From each testis there arises, usually from the inner ventral margin, a vas deferens, (vd. Figs. 4, Pl. C, 11 and 12, Pl. D). The place of origin of the vas deferens with respect to the testis is not constant as it may sometimes arise even from the outer margin, as in the fifth testis of the left side, (Figs. 4 and 11). After leaving the testis the vas deferens arches dorsally and outward, finally uniting with the vas deferens communis (vdc) for that side. The vas deferens communis takes its origin in the vas deferens of the sixth testis, running dorsad and cephalad, dipping slightly to receive the vas deferens from each testis. After passing into somite XIII it bends vetrad and medially. In somite XII it turns sharply dorsad, then cephalad and ventrad; then comes a more or less complete loop which joins the larger vesicula seminalis, (vs, Figs. 11, 12 and 13, Pl. D). The vesicula seminalis arches dorsad, cephalad and ventrad, then again turning cephalad becomes continuous with the smaller ductus ejaculatorius, (d, Figs. 11, 12, 13 and 14, Pl. D) at about XI/XII. The ductus ejaculatorius winds about in somite XI with several loops and at the front of the somite becomes greatly enlarged into the end portion(s) which Whitman, '91, has shown, in *Clepsine plana,* to secrete the spermatophore. This enlarged portion arches dorsad, caudad, and ventrad, and then turns to the median line where it joins the similar duct from the opposite side in a common atrium (a, Fig. 15 and Figs. 13 and 14, Pl. D). This common cavity opens, by a narrow passage with thick muscular walls, into the enlarged bursa (b) which connects with the outside by means of the male genital pore.

The course of the genital duct is very nearly constant in different individuals and is often an important factor in determining species. Barrows, '93, referring to this fact, said, "It is found that in two species of Aulostoma . . . the relation between the nerve cord and the sperm duct (vas deferens) is constant:—the right sperm duct always passing under the nerve cord in one species and to the left in the other. In some cases where the external specific differences are so small as to require the closest examination for their detection the positional relation of the ducts of the reproductive organs to the nerve cord will set aside the difficulty."

The histology of the male duct corresponds on the whole with *C. plana* (Whitman, '91) and the different parts probably perform the same functions; the enlarged portion of the duct (vs) serving as a reservoir for mature spermatozoa, and the enlarged terminal

portion secreting the spermatophore. This must, however, remain a matter of conjecture until more is learned concerning its habits, as neither spermatophores nor other methods of reproduction have been observed. The atrium (a, Fig. 15, Pl. D) is lined dorsally with long columnar epithelium which is continuous with the glandular epithelium of the vas deferens communis. This epithelium becomes very much shorter at the base of the atrium, losing its glandular appearance and in the narrow opening joins the cuboidal, ectodermal epithelium which lines the bursa. (b, Fig, 15, Pl. D.)

The female reproductive organs consist of the ovaries, (ov, Figs. 4, Pl. C, 11 and 12, Pl. D) and a pair of simple sacks lying nearly horizontally in segments XIII and XIV between the two sperm ducts. Near the anterior end each ovary sends a branch ventrally which, turning toward the median line, unites with the branch from the opposite side and opens on the surface by means of the female pore, (♀ , Fig. 3, Pl. C and Figs. 11 and 16, Pl. D). At its anterior end the ovary forms a caecum which extends forward in front of the female pore nearly to the atrium of the male ducts. It is entirely probable that the ovaries would be much larger in older specimens taken when the eggs were approaching maturity.

Glands.

Oesophageal and Salivary Glands.

The oesophageal glands, (oeg. Figs. 4, 9 and 10, Pl. C) are paired glands lying in somites X and XI which empty by a short duct into either side of the oesophagus in somite XI. The lumen of the glands is large and open and sends off numerous short pockets or alveoli. The whole gland is lined with a columnar epithelium of striated gland cells. The striation in these cells is very pronounced and extends from the free end of the cell clear through to the wall resting on the basement membrane. Between these cells are wedged, here and there, smaller supporting cells (sc. Fig. 10, Pl. C) containing small, darkly staining nuclei. In the short duct which joins the oesophagus, the gland-cells gradually become smaller, at the same time losing their striations, and pass over into the regular oesophageal epithelium.

These glands are not to be confused with the salivary glands ("Halsdrüssen" Apathy, '98) which are in all cases unicellular, and are, in this species, widely distributed among the tissues

through the anterior two thirds of the body. The ducts from these cells form two bundles, situated dorsally, inside the longitudinal muscles, at either side of the median line. These bundles of ducts enter the proboscis near its base and continue forward among the muscle bands, finally emerging near its tip.

Although I have hunted through all of the available literature, I have been unable to find any description of glands similar to what I have above called oesophageal glands. The only reference I can find to such glands are in Whitman, '91, for *Clepsine plana* and Siegel, '03, for *Placobdella catenigra* M. T. Whitman's Fig. 5, Pl. XIV, in the Journal of Morphology, Vol. IV, shows two obscure bodies in a position which are designated as "oeg." The explanation of this figure gives "oeg.=oesophageal pair of glands." I have looked through his description carefully and find no other reference to them. Siegel figures similar glands for *Placobdella catenigra* and makes them the temporary abiding place of the sporocites of *Haemogregerina stepanovi,* from which they are transferred to the turtle. No details of structure are shown in his figures and no description of the glands is given in the text. Castle, '00, neither figures nor describes them for *Placobdella parasitica* although sections of this species in my collection show similar glands to be present.

Posterior Sucker Glands.

Beginning with about somite XX and throughout the remaining posterior portion are to be found numerous posterior sucker glands which, in general, bear a close resemblance to the salivary glands but stain much more deeply with Ehrlich-Biondi stain. The ducts from these glands are very small, and form several bundles among the tissues, finally opening upon the posterior sucker.

Nephridia.

The nephridia are fifteen in number and are found in all the somites from VIII to XXIII with the exception of somite XII in which the generative ducts are large and the nephridia are lacking. The nephridopores are latero-ventral and are to be found a little anterior to the center of the sensory annulus. The nephridial funnels open into the coelomic cavity latero-dorsally (n. f. Fig. 7, Pl. C). The funnel, (Fig. 8, Pl. C), consists of three ciliated crown

cells ("Kronenzellen", Graf, '99) and a short stile cell which opens into the larger receptaculum.

In conclusion I wish to acknowledge my great indebtedness to Professor Nachtrieb, under whose direction this work was done, for his kindly assistance and many valuable suggestions; and to the Alumni Association of the University of Minnesota for fellowship privileges enjoyed during the year 1903-4.

PLATES C TO E
AND
EXPLANATIONS

Part II

General Legends of Plates C, D and E.

a.....atrium.
an.....anus.
b.....bursa.
cc.....crown cell.
coe.....coelom.
de.....ductus ejaculatorius. Ejaculatory gland of the sperm duct.
e .....eye.
fav. n.....Nerve of Faivre.
gc.....gland cell.
i.....intestine.
m.....muscle.
nf.....nephridial funnel.
oc.....cæcal portion of ovary.
oe.....oesophagus.
oec.....oesophageal collar.
oeg.....oesophageal gland.
ov.....ovary.
ovd.....oviduct.
prob.....proboscis.
rec.....receptaculum.
s.....enlarged portion of vas deferens communis.
sc.....supporting cell.
stc.....stile cell.
stn.....stomato-gastric nerve.
T.....testis.
V2.....second branch of nerve V.
vd.....vas deferens.
vdc.....vas deferens communis.
vs.....vesicula seminalis.
wc.....wandering cell.
♂.....male genital pore.
♀.....female genital pore.

I, II, III, etc. in Fig. 4 of Plate C refer to the somites but in all other figures they refer to somatic nerves.

1, 2, 3, etc.=ganglion packets of somatic ganglia I, II, III, etc. respectively.

PLATE C.

Placobdella pediculata.

Figs. 1, 2 and 3. Lateral, dorsal and ventral view respectively.

Fig. 4. Dorsal view of a young specimem, showing the constitution of the somites and the positions of the organs.

Fig. 5. Portion of the isthmus of Aplodinotus grunniens, showing holes produced by the posterior sucker of P. pediculata.

Fig. 6. Longitudinal section of one of the holes shown in figure 5.

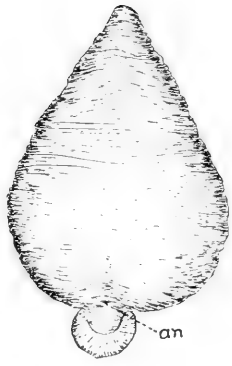
Fig. 7. Transverse section thru somite XIX, showing the position of the nephridial funnel on the left side.

Fig. 8. A nephridial funnel.

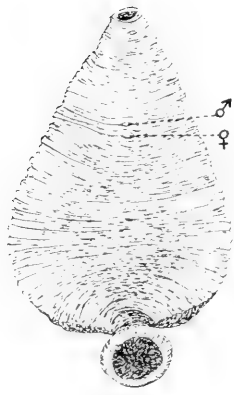
Fig. 9. Drawing of a model of the esophageal glands and the position of the esophagus into which they empty.

Fig. 10. Section thru three alveoli of the esophageal gland, showing the striated gland cells. From a specimen hardened in Gilson's mercuro-nitric mixture and stained in paracarmine and Lyons blue.

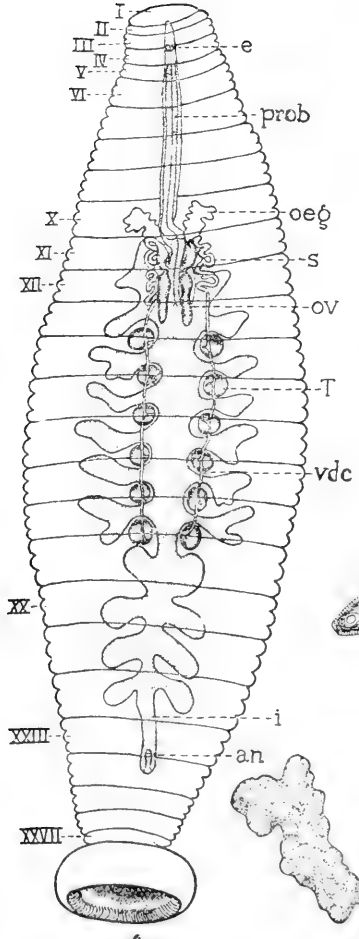
1



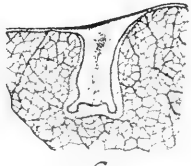
2



3

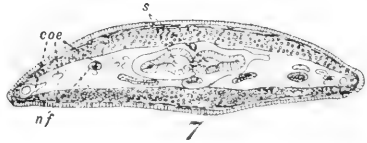


4

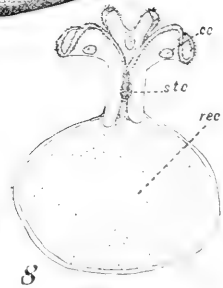


6

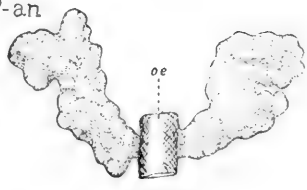
5



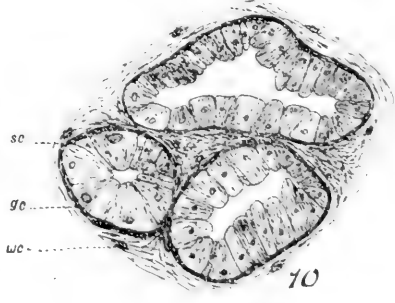
7



8



9



10

PLATE D.

Placobdella pediculata

Fig. 11. Lateral view of the generative organs. Reproduction of a photograph of a wax model. The ovary and convoluted portion of the male duct were reconstructed by the Born method, while the testes and vas deferens commune immediately above them were modeled after careful measurements and then attached to the anterior part.

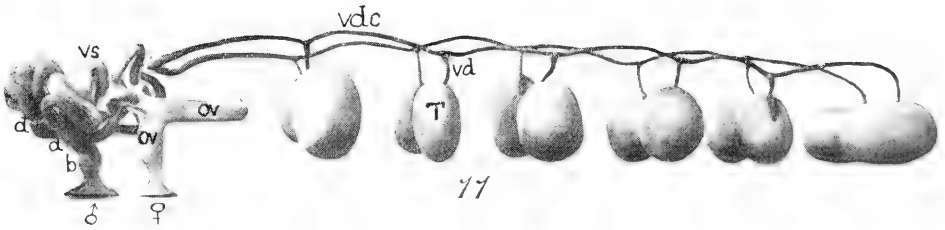
Fig. 12. The same as figure 11, dorsal view.

Fig. 13. Lateral view of the anterior portion of the male duct.

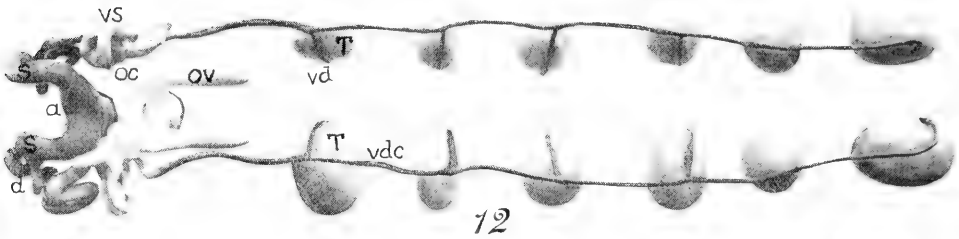
Fig. 14. Frontal view of the anterior portion of the male ducts.

Fig. 15. Sagittal section of the male genital pore, showing the position of the atrium (a) and the bursa (b).

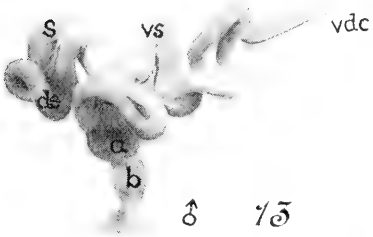
Fig. 16. Section thru the female genital pore.



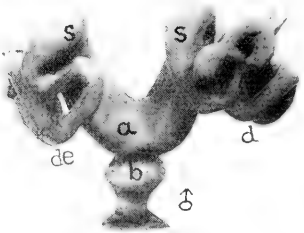
77



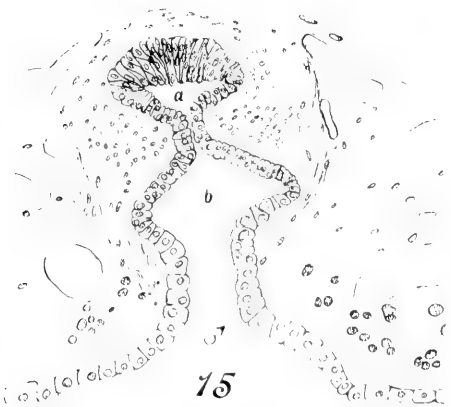
72



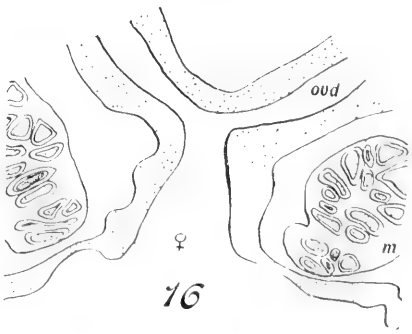
♂ 73



74



75



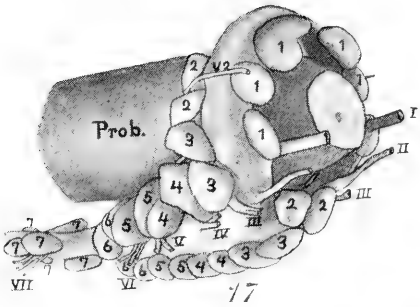
76

PLATE E.

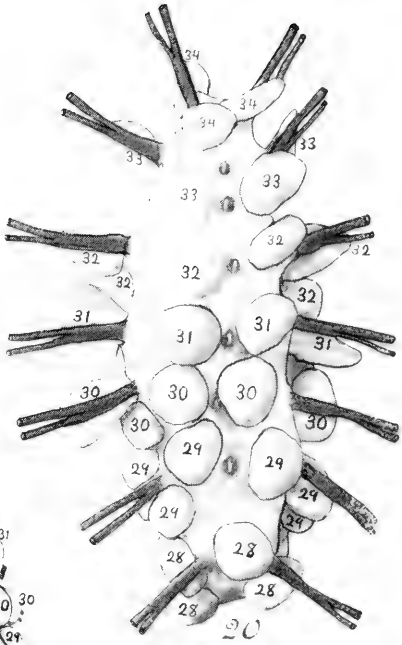
Placobdella peliculata

Figs. 17, 18 and 19. Right lateral, ventral and left lateral view respectively of the anterior portion of the central nervous system with a portion of the proboscis. Reproductions of photographs of a wax model made by the Born reconstruction method.

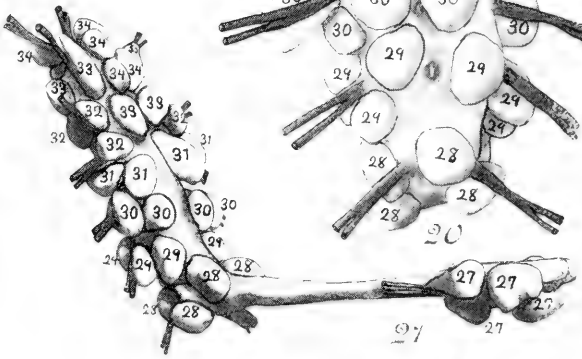
Figs. 20, 21 and 22. Posterior, lateral and frontal view respectively of the posterior ganglionic mass. Photographs of a wax model made by the Born reconstruction method.



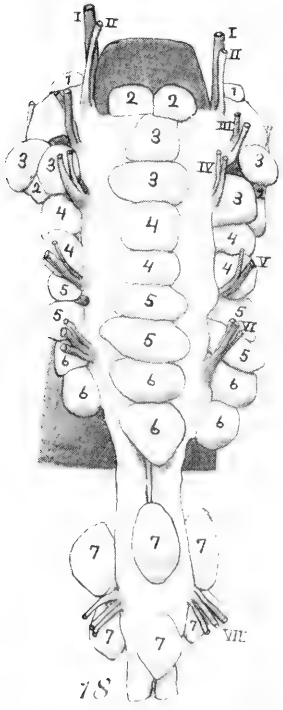
77



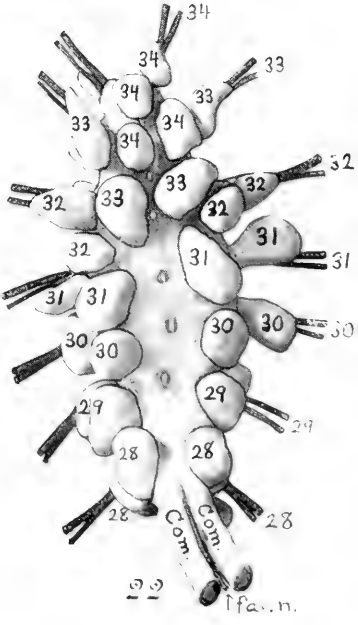
90



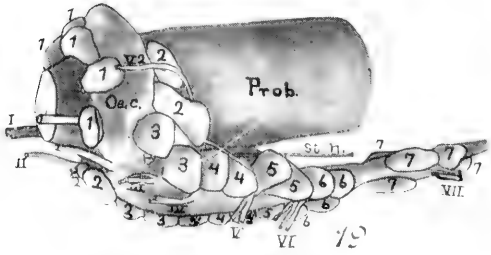
91



78



92



79

PART III

CLASSIFICATION
OF THE
LEECHES OF MINNESOTA

BY
J. PERCY MOORE

INTRODUCTION

That the lake region of Wisconsin, Minnesota and Manitoba abounds in leeches of large size and great variety has long been known, and has been commented upon frequently by visitors to that well-watered area. The very first recognizable descriptions of North American leeches, published by Thomas Say in 1824, were based upon examples observed in the territory about Lake Vermillion in Minnesota. Since that time a number of additional species have been described from localities about the western end of Lake Superior.

The richness of the leech fauna of Minnesota is fully established by the splendid collections, gathered by the State Zoological Survey under the direction of Professor Henry F. Nachtrieb, which form the chief basis of this report. The entire State is not represented in the collection, most of which came from the northern section, chiefly from Lake Vermillion, Leech Lake, Mille Lacs and their environs. Yet it includes twenty species—a number probably greater than could be found in an area of equal size elsewhere in the United States, or, so far as has been recorded, anywhere else in fresh water. Leeches generally have a wide geographical distribution and the presence of most of these species in other parts of the state is to be expected, as many of them range through the entire northern tier of states or even beyond, several are circumpolar, and one, *Glossiphonia stagnalis,* is almost cosmopolitan. The occurrence of a considerable number of the species in the southern portion of Minnesota has been ascertained through material received from other sources, the most important being a collection sent to me by Prof. Henry L. Osborn, which, indeed, adds one species, *Placobdella hollensis,* not represented in the Survey collections.

The plan of this report is to give descriptions, which are something of a compromise between the technical and popular, of the salient features of the entire organization of each species, omitting altogether those minutiae which require more than a simple microscope or ordinary methods of dissection for their verification. Fuller descriptions of many of the species will be found in a paper by Castle, Some North American Fresh-water Rhynchobdellidae,

in the Bulletin of the Museum of Comparative Zoology, Vol. XXXVI, (1900) pp. 16 to 64, and one by Moore, The Hirudinea of Illinois, in the Bulletin of the Illinois State Laboratory of Natural History, Vol. V (1901) pp. 479-547. The literature lists included in these two papers will enable one to ascertain the principal papers in which North American Hirudinea have been discussed.

Characteristic features in the anatomy or exterior have been figured for all of the species, in most cases from Minnesota representatives, but new species or those which have not been figured previously are treated in greater detail.

Of the biological relations of leeches to other animals much remains to be learned and this field affords a rich opportunity for exact observation. Likewise the breeding and other habits of many species are unknown or known only imperfectly. The remarks on this side of the subject which follow the descriptions are based on observations made chiefly in the vicinity of Philadelphia.

The drawings of the frontispiece are colored from living examples taken, with the exception of *Hæmopis grandis*, near Philadelphia.

KEY TO THE SPECIES

OF

MINNESOTA LEECHES

KEY TO THE SPECIES DESCRIBED IN THIS PAPER

The bold-faced numbers refer to the page.

I. Mouth a small pore-like opening in the disk of the anterior sucker, through which a muscular pharyngeal proboscis may be protruded.

A. Complete somites formed of three annuli.

a. Genital orifices separated by a single annulus; eyes one pair, distinct.

b. A dark brown cuticular plate and underlying gland on the dorsum of somite VIII.

1. Body capable of great extension; color pale—pink, gray or brownish.

Glossiphonia stagnalis, 77

bb. No nuchal plate or gland in the adult.

2. Body very slender, elongated and little flattened; very transparent owing to the nearly complete absence of pigment; no cutaneous papillae. **Glossiphonia nepheloidea, 76**

3. Body relatively broad and flat; more or less heavily pigmented with brown arranged in linear pattern, annulus *a*2 marked by white spots usually arranged in transverse rows; three longitudinal series of conspicuous black papillae. **Glossiphonia fusca, 80**

aa. Genital orifices separated by two annuli; eyes in several pairs.

4. Three pairs of eyes; gastric cæca six or seven pairs; a pair of dark longitudinal lines both above and below.

Glossiphonia complanata, 82

5. Four pairs of sub-equal eyes, all simple; gastric cæca nine pairs. **Hemiclepsis occidentalis, 96**

6. One pair of compound eyes followed by three or more pairs of much smaller simple eyes; gastric cæca seven pairs.

Plocabdello hollensis, 94

aaa. Genital orifices separated by two annuli; a single pair of compound eyes; gastric cæca, seven pairs, branched.

b. Somites I to V much widened to form a distinct head.

7. Somites I and II biannulate; the dorsum marked by three strong papillated keels; gastric cæca much branched. **Placobdella montifera, 88**

bb. Anterior somites not especially widened.

c. Posterior sucker very free and supported on a slender peduncle; anus at XXIII/XXIV; gastric cæca little branched.

8. Body rather high, very contractile; dorsal papillae wanting. **Placobdella pediculata, 90**

cc. Posterior sucker not supported on a specially slender peduncle; anus at XXVII/XXVIII; gastric cæca much branched.

9. Body very much depressed; dorsal papillæ few, low and smooth; integuments rather opaque. **Placobdella parasitica, 84**

10. Body very much depressed; dorsal papillæ numerous, rough and usually high; integuments translucent. **Placobdella rugosa, 86**

AA. Complete somites composed of more than three annuli.

11. Complete somites consisting of six unequal annuli; posterior sucker very large and provided with a marginal circle of contractile papillæ; eyes one pair contiguous in middle line. **Actinobdella inequiannulata, 99**

12. Complete somites consisting of twelve or fourteen approximately equal annuli; body divided into two regions; posterior sucker without marginal papillæ; eyes widely separated on posterior part of head. **Piscicola punctata, 103**

II. Mouth large, the sucker appearing as its bounding lips; the pharynx not forming a protrusible proboscis.

A. Eyes five pairs, arranged in a regular arch on somites II to VI; genital ducts with complex copulatory apparatus; testes strictly paired, their number moderate; at least one pair of gastric cæca present.

a. Jaws prominent, bearing many small teeth arranged in one series; accessory copulatory glands present and opening in pores behind the female genital orifice.

13. Teeth about sixty-five in each jaw; genital pores separated by five annuli; the dorsum marked with median red and marginal black spots, both metameric.

Macrobdella decora, 106

aa. Jaws prominent, bearing a few coarse teeth arranged in paired series; no accessory copulatory glands.

14. Teeth twelve to sixteen pairs on each jaw; the primary annuli VII*a3* and VIII*a1* enlarged, but only partially divided into secondary annuli; color variable but marked more or less thickly with non-metameric black blotches. **Hæmopis marmoratis, 110**

15. Teeth twenty to twenty-five on each jaw; the secondary annuli VII*b5* and *b6* and VIII*b1* and *b2* completely formed; color nearly uniform, usually with a median dorsal dark stripe and few or no blotches.

Hæmopis lateralis, 113

aaa. Jaws absent or rudimentary; no teeth; no accessory copulatory glands.

16. Male genital orifice at XI *b5/b6;* the female at XII*b5/b6;* color pattern consisting in part of close or distant blotches of dark pigment, ventral ground color lighter than dorsal.

Hæmopis grandis, 117

17. Male and female genital orifices constantly at the middle of XI*b6* and XII *b6* respectively; a few distant dorsal blotches or none; no ventral blotches, ventral ground color not paler, usually darker than dorsal, the rufous or orange marginal stripe conspicuous.

Hæmopis plumbeus, 115

AA. Eyes three or four pairs, not arranged in a regular arch, two pairs situated on somite IV; genital ducts relatively simple, without complex copulatory apparatus; testes numerous, not regularly paired; no gastric cæca.

a. Annulus b6 not obviously enlarged and subdivided.

18. Eyes three pairs; male orifice at XII*b3/a3*, female at XII*b5/b6;* atrial horns simply curved and vas deferens reaching forward to the level of ganglion XI.

Erpobdella punctata, 121

aa. Annulus *b6* obviously enlarged and subdivided.

19. Eyes four pairs; male orifices at XII*b3/a3*, female at XII *b5/b6;* atrial horns spirally turned, vas deferens reaching forward to the level of ganglion XI.

Nephelopsis obscura, 123

20. Eyes four pairs; male orifice at XII *b1/a3* or occassionally XII *a3/b5*, the female at XIII *b1/b3*, atrial horns simply curved, vas deferens reaching forward to ganglion XI.

Dina parva, 125

21. Eyes three or four pairs; male orifice at XII *b3/a3*, female at XII *b5/b6;* atrial horns simply curved, vas deferens not reaching anterior to atrium. **Dina fervida, 127**

DESCRIPTIONS

OF

FAMILIES, GENERA AND SPECIES

DESCRIPTIONS OF FAMILIES, GENERA AND SPECIES

Family Glossiphonidæ.

Leeches of medium or small size; generally rather short, broad and much flattened, rarely slender and elongated. No distinct clitellum. Caudal sucker usually large and flat; oral sucker rather small and, except in a few cases, scarcely expanded. Complete somites of middle region usually of three rings, rarely of 2, 5 or 6. Eyes 1-4 pairs, situated in a longitudinal row close to the median line; the first pair often compound, the others simple. Dorsum often studded with cutaneous papillae in addition to metameric sensillae. Mouth a small pore in the oral sucker. Pharynx a slender, protrusible proboscis without jaws or teeth. Salivary glands present. Stomach with from one to ten pairs of lateral, simple or branched cæca. Intestine with four pairs of cæca. Genital orifices separated by one to four rings, the ♀ in somite XII and the ♂ in XII or between XI and XII. Testes sacs usually six, rarely nine pairs; sperm ducts divided into a very slender vas deferens and a large epididimis and ductus ejaculatorius, the latter of which opens into a small median atrium without a penis. Ovisacs a pair of slender convoluted tubules opening together at the female orifice without a vagina. Fertilization by means of horny spermatophores attaches to the integument from which the spermatozoa penetrate the tissues to the ovisacs. Eggs and young borne on the ventral surface of the parent. Strictly fresh water. Tortoise and snail leeches, which feed on snails, small worms, etc. or suck the blood of tortoises, frogs or fishes, rarely fixed parasites of the latter. Creepers, mostly poor swimmers.

Genus Glossiphonia Johnston.

Moderately depressed or elongated and nearly terete. Eyes 1-3 pairs, all simple. Cutaneous papillae few or none, never strictly median. Pharyngeal salivary glands diffuse; gastric cæca 1-7 pairs, simple or slightly branched. Sperm ducts forming a pair of long, open loops extending through several segments. Chiefly free-living or attached to invertebrates.

Glossiphonia nepheloidea (Graf).

(Plate I, fig. 2)

Clepsine nepheloidea Graf (1899).
Glossiphonia elongata Castle (1900).

Description—This species, which may be called the worm leech, is readily distinguished from any other member of its family belonging to this fauna by its slender, elongate, and sub-terete form. Slightly smaller and much narrower than *G. stagnalis* its great power of extension permits full grown individuals to exceed that species in length. Both the head and caudal sucker are very small and weak, and the axis of the latter nearly coincides with the axis of the body. A single pair of widely separated eyes show their faintly pigmented cups within the anterior part of somite IV. The skin is smooth and lacks integumental papillæ altogether; the muchal gland and plate are also lacking in the adult.

For the most part the annuli are very distinct, regular, smoothly rounded and simple, but the furrows of the head region are mostly faint and usually require special preparation to make them visible. Somites I and II are united into a single annulus or are separated only by a faint furrow; III, IV, and V are biannulate, the first annulus being the larger in each case; VI to XXIV, inclusive, are triannulate, and XXV, XXVI and XXVII each uniannulate but distinct.

The relatively large mouth is located in somite III. In correlation with the narrowness of the body the stomach is a nearly simple straight tube bearing the last pair of reflexed cæca only, and even these are shorter than in allied species. The salivary glands are small and of the diffuse type.

As is the condition in many of the smaller species of Glossiphonia the genital orifices are separated by only one annulus, the male being in the furrow XII *a1/a2*, the female XII *a2/a3*. There are six pairs of testes occupying the customary positions, and the vas deferens is folded into a long post-atrial loop, the terminal limb of which is an enlarged sperm sac. The longitudinal musculature is weak and diffuse.

The body of the species, particularly in its anterior part, is remarkable for its transparency and is almost totally devoid of superficial pigment. The walls of the stomach and intestine exhibit more or less of a yellow or pale orange color which is the prevailing tint of the posterior region of the body.

Habits—*Glossiphonia nepheloidea* is by no means an abundant leech and has been until recently generally overlooked, a result no doubt in large part due to its inconspicuous coloring and seclusive habits rather than its scarcity. Only four specimens, all taken from Lake Pepin by means of a pump, represent the species in the Minnesota collections. Whitman, Graf and Castle have found it only in ponds in Massachusetts. In my experiences it occurs much more numerously in running water among plants, particularly along the muddy flats exposed at low water along the Delaware River, associating with *G. stagnalis, G. complanata* and sometimes other species.

In appearance and movements it is much more worm-like than any other species of Glossiphonia. Its weak suckers and deficient musculature ill fit it for active creeping and, being incapable of swimming and of a manifestly sluggish disposition, it moves about but little and chiefly in the very unleechlike manner of crawling through the ooze. When exposed in its place of concealment it writhes and twists in a peculiarly helpless fashion, often for a long time not even attempting to attach the suckers and never exhibiting that decision of movement and promptitude to seek concealment which is shown by *G. stagnalis.* Its means of protection consist largely in the very copious mucous secretion which envelopes the body when irritated.

Although, like *G. stagnalis,* this leech will feed on snails and worms and even suck blood when the opportunity offers, it is essentially a scavenger and feeds largely on the substance of dead animals and on ooze.

Glossiphonia stagnalis (Linn.) Johnston.

(Plate I. fig. 1.)

Hirudo bioculata Bergmann (1757)
Hirudo stagnalis Linnaeus (1758)
Clepsine modesta Verrill (1872)
Helobdella stagnalis Blanchard (1896)

Description—*Glossiphonia stagnalis* is a small leech somewhat larger and decidedly stouter than *G. nepheloidea.* Large individuals may reach a length of an inch when fully extended and in that state would be fully twice the width of a *G. nepheloidea* of the same length. When contracted to one-half that length, which is about the ordinary resting condition, they would be about three

times the width of *G. nepheloidea* and much more flattened, but still decidedly convex above. The head is small but moderately distinct, less elongated and more strongly annulated than in *G. nepheloidea*. The caudal sucker is well developed, strongly directed ventrad, and but little exposed posteriorly; its axis ordinarily at about right angles to the body axis. While only one pair, situated as in *G. nepheloidea*, the eyes are much more conspicuous owing to the greater amount of their pigment. A conspicuous feature is the more or less deep brown chitinoid plate and underlying gland situated on the dorsum of VIII *a1* and *a2*.

There are no distinct integumental papillae though the surface may be somewhat roughened with scattered sense organs. The metameric sensillae are inconspicuous as in *G. nepheloidea*.

The annulation is distinct throughout, especially at the caudal end, where the annuli are angulated at the margins. Somites I and II are usually completely united in the short prostomium; III is uniannulate or occassionally faintly subdivided; IV and V are biannulate, the latter more completely and sometimes showing indications on the dorsum of the furrow *a1/a2;* VI to XXIV are triannulate, and XXV and XXVI biannulate, the latter occassionally being united with XXVII, which is commonly represented by a pair of wedged-shaped halves nearly sundered by the anus.

The mouth is smaller but otherwise similar in form and position to that of *G. nepheloidea*. Diffuse salivary glands extend through somites XII to XIV or sometimes farther. Never more than six pairs of gastric cæca are present, but the number is variable and may be reduced to three pairs by the obliteration of the first three. All are simple and unbranched and increase in size from the first to the sixth pair, the last being much the largest and reflexed caudad through three or four somites (XIX to XXII).

The external genital orifices and the reproductive organs generally are essentially like those of *G. nepheloidea*. The longitudinal muscle cells are arranged diffusely but are strongly developed.

Pale gray, pink, brownish or greenish tints, which are much affected by the contents of the alimentary canal seen through the more or less translucent tissues, are the colors of this species. Young specimens and some adults are almost colorless and translucent, but commonly the tissues of the larger ones are rendered opaque by the presence of numerous reserve and pigment cells.

Habits—Judging by the material which represents it in this collection this nearly cosmopolitan species must be much less abundant in the lakes of Minnesota than in many other sections of this country and especially the northeastern portion from Illinois to Maine. It is found everywhere but abounds especially in warm shallow waters of streams, pools and ponds and along the shores of lakes and rivers; it is the common pond leech. In all suitable localities it gathers in numbers on the under sides of stones, sticks and fallen leaves or conceals itself between the ensheathing leaf stalks of rushes and other aquatic plants. Less often it attaches itself to the bodies of larger leeches, such as *Macrobdella* and *Haemopis,* to fresh water snails, mussels, fishes, turtles and more rarely to frogs. It is perhaps transported on the legs of aquatic birds. Like most of the *Glossiphoniæ* it does not swim, but when disturbed creeps with considerable activity to a place of concealment, when, if still further disturbed, it rolls into a ball in the manner of a "pill bug" and falls to the bottom, then quickly unrolls and creeps away to a dark shelter.

Ordinarily its food consists of small annelids, insect larvæ, snails, and small bivalves like *Pisidium* and its allies. Numbers also congregate and feed upon dead bodies of larger animals, such as crustaceans, fishes and frogs; and when occasion offers blood will be drawn from injured fishes, frogs and other vertebrates, including the feet of wading boys. Vast numbers frequent the fishing stations along the Delaware River, attracted no doubt by the quantities of bloody offal thrown into the water at such places. Under such conditions the stomach of every individual will be distended with blood, and, comparing Castle's description of the alimentary canal with my own observations, I am led to suspect that the capacity of the gastric cæca may be increased in individuals which habitually subsist upon such diet.

On the other hand this little leech is frequently devoured by the large predaceous leeches, sunfish, perch and other small carnivorous fishes. Along the shores of tidal rivers, like the Delaware, various species of snipe and sandpipers, which feed on the flats exposed at low water, pick them from the shingle and gravel.

Breeding begins in early spring and extends into the early summer. During the latter part of April and early May almost every individual bears its burden of eggs or young. In streams and ponds of cold water ovi-position occurs later than in warmer waters. In

some localities a second brood is raised in late summer. As in most closely related forms the eggs are not attached directly to the body but are contained several together in small mucoid sacs, of which mature individuals bear from eight to twelve or fifteen attached to the posterior ventral surface. When bearing eggs or young the rhythmic oscillating respiratory movements become much more frequent and vigorous than at other times. When disturbed the brood is protected by enveloping it in the margins of the body folded toward the middle line and by rolling into a ball.

Glossiphonia fusca Castle.

(Plate I, fig. 3)

Clepsine papillifera var. *lineata* Verr. (1874)
not *Hirudo lineata* Müller (1774)
Glossiphonia lineata Moore (1898)
Glossiphonia fusca Castle (1900)

Description—The form is rather short and thick and relatively broader than the other small *Glossiphoniæ* described in this paper. In size it is about equal to *G. stagnalis* but lacks the great power of extension of that species. Typically the back bears three longitudinal series of small but prominent sharp conical papillæ, an irregular median series, really formed of a pair of closely approximated series reduced to one by fusion or loss of some of the members, and two dorso-lateral series situated half-way between the middle and the margins. Sometimes two more are added external to the latter, one on each side, but these latter are always very incomplete. There is a single pair of remarkably large eyes situated as in *G. stagnalis*. No nuchal gland is present.

Somites I and II are uniannulate or completely united; III and IV are biannulate, the larger annulus of the latter partly divided by an incomplete furrow *a1/a2;* V is generally triannulate dorsally, but biannulate ventrally. Somites VI to XXIV are fully triannulate, XXV and XXVI biannulate, the latter incompletely in most cases, and XXVII uniannulate. The postanal annulus is very large.

The mouth is situated as in *G. stagnalis* but is rather larger and the proboscis wider than in that species. There are six pairs of gastric cæca, strictly simple or slightly lobed, and the first is sometimes wanting; the last reflexed as usual. The salivary glands are diffuse but much more extensively developed than in the preceeding species.

The testes are present in the same number and occupy the same positions as usual, each lying just anterior to the base of one of the gastric cæca. A long posterior loop of the vas deferens, partly enlarged as a sperm sac, is developed and extends through the ventral sinus to somite XV or beyond.

The colors are plain but very pretty and exhibit a considerable range of variation. The ground is ash or grayish brown, plain below, but on the dorsal side generally marked by numerous narrow longitudinal lines of brown pigment cells which give to that surface a generally brown effect. The entire preocular region is perfectly white, and the neural annuli, for most of the length of the body, are marked with two, four or six white spots arranged in regular longitudinal series and flanking the three or five rows of cutaneous papillæ which, owing to their black color, are by contrast very conspicuous. Sometimes the white spots fuse into metameric transverse bars and more rarely they are absent.

Habits—This handsome little leech is much less common than *G. stagnalis,* though in some localities it occurs in abundance along with that species and *G. complanata.* It seems to be more partial to colder waters than either of these species and is sometimes found in springs where they do not occur. In ponds it frequently fastens itself upon the shells of the larger species of Lymnæa and other snails and more rarely to the larger leeches. Less active than *G. complanata* it feeds less frequently upon active worms and larvæ but confines its attacks almost exclusively to the smaller snails. snails.

In placing its eggs in a small number of large capsules this species resembles *G. complanata,* but it breeds later than that species, continuing far into the summer (as late as Aug. 6th) to carry newly laid eggs.

Concerning the name of this species it should be said that Verrill's name *lineata,* although the earliest, must be discarded on account of Müllers earlier use of *Hirudo lineata* which is clearly a *Glossiphonia* and probably *G. complanata,* though so far as I know it has been definitely determined. *Glossiphonia triserialis* E. Blanchard (1849) bears a remarkably close resemblance to our species and was at one time regarded by me as identical with it, but R. Blanchard has recently repeated (1900) his earlier statement (1896) that the genital orifices are separated by two annuli in this species and not by one as in *G. fusca.*

Glossiphonia complanata (Linnæus) Johnston.

(Plate I, fig. 4)

Hirudo complanata Linnæus (1758)
Clepsine elegans Verrill (1874)

Description—Although not much exceeding the species previously described in length when extended this leech is considerably larger and more bulky than any of them. The body is rather broad and flat with thicker margins, though *G. fusca* approaches it in this respect, and like that species it is incapable of great extension. In this connection it is interesting to note that both of these species have remarkably well developed longitudinal muscles. The head is not distinctly widened and the posterior sucker is small but powerful and less strongly directed ventrad than in the large species of *Placobdella*. There are at least four series of low, rounded but rather large cutaneous papillæ on which the dorso-median and dorso-lateral sensillæ are borne. There is no median series. Numerous small sense organs roughen the integument, which is rather opaque. A character which is quite unique among the *Glossiphonidæ* herein described is the presence of three distinct pairs of eyes situated on somites II, III and IV respectively. They are close together near the middle line and the pigment cups of the first are sometimes in contact, while the second are farthest apart and the largest in size. There is no nuchal gland.

Somites I and II are uniannulate, sometimes indistinctly separated; III is uniannulate or indistinctly biannulate; IV is biannulate, divided by a rather faint furrow into a larger anterior and a smaller posterior annulus. The next somite (V) is biannulate or more usually triannulate by the separation of *a1* by a shallow furrow from *a2*. Somites VI to XXIV inclusive are fully triannulate; XXV is biannulate and XXVI and XXVII usually uniannulate, the former frequently exhibiting some marginal division.

The mouth is of relatively large size and placed at the boundary between the second and the third somites. Like the closely related species the salivary glands are diffuse. Six or seven pairs of simple or slightly branched gastric cæca are present, the last reflected but relatively shorter than in the blood-sucking species of *Placobdella*. The longitudinal muscles of this species are remarkably powerful.

Unlike the three species of *Glossiphonia* described above the genital orifices of this species are separated by two annuli, the male

being situated at XI/XII, the female XII *a2/a3*. The vasa deferentia have the customary long posterior loops and enlarged sperm sacs. A very remarkable feature and one that is peculiar to this and a few very closely allied species is the presence of nine or ten pairs of testes in place of the six pairs usually present. The additional pairs are added at the caudal end of the series in somites XX to XXIII.

A more or less obvious narrowly striped pattern results from the more superficial pigments showing through the rather opaque integuments along the lines of the longitudinal muscles. The general effect is a somewhat heavy green or brown ground color marked dorsally and ventrally by a pair of very conspicuous longitudinal brown lines which above begin just behind the eyes while below they are slightly farther apart. The dorsal lines are broken into a series of short dashes by small metameric white or sulphur yellow spots corresponding with the dorso-medial papillae on the neural annuli. Four or five additional series of similar spots occur on the neural annuli, making six or seven in all. Of these the median series is the least constant, the others including the four constant papillæ, to which two marginal series must be added.

Habits—The snail leech, as this species is named in England, abounds in certain localities in the shallows of rivers and large ponds, where it is found concealed beneath stones. It is remarkable among the small glossiphonids for its great muscular strength, which enables it to overcome its prey and to adhere to stones with great tenacity. While more tardy in seeking to escape when disturbed than its most usual associate, *G. stagnalis*, it is more active in its movements when once aroused. It is more prone than most species to roll into a ball and may remain quiescent in this condition for a considerable period.

Although occasionally found attached to turtles the snail leech has not been observed to suck blood, but so far as my observations extend feeds exclusively in its natural habitat on small snails, worms etc., which its strength enable it to quickly overcome.

As usual the eggs are carried on the ventral side of the body and their large number, as well as the great length of the breeding season, render this one of the most satisfactory species for embryological study. It is one of the earliest as well as one of the latest of the Glossiphonias to bear eggs, which are contained in a small number of unusually large capsules.

Genus Placobdella R. Blanchard.

Body widened and moderately or excessively depressed. Suckers variable, the caudal sometimes with minute marginal serrations. Eyes usually one pair, compound, on somite III, rarely followed by several pairs of imperfect simple eyes. Cutaneous papillae variable, but usually numerous and some median. Pharyngeal salivary glands large and compact; gastric cæca seven pairs, very large and much branched in the flatter species. Sperm ducts without loops, compacted and much convoluted. Parasitic on turtles, fishes and batrachians, or free-living.

Placobdella parasitica (Say) Moore.

(Plate I, figs. 7, 8)

Hirudo parasitica Say (1824)
Glossiphonia parasitica Castle (1900)
Placobdella parasitica Moore (1901)

Description—Of all of our numerous species of glossiphonids this attains the largest dimensions. Ordinarily examples are about two inches in length when extended, the giants upwards of four inches in the same condition. The form is broad, very flat and foliaceous particularly when food is absent from the cæca. In extension the head is somewhat expanded, but in contraction partakes of the general ovate pyriform outline of the body. The posterior sucker is of large size and considerably exposed behind the body, the plane of its adhesive surface being parallel with the ventral surface of the body. Cutaneous papillæ are numerous but inconspicuous, low and smooth; sometimes they are obsolete. The most constant are disposed in three longitudinal series on the neural annuli and two longitudinal series on the post-neural annuli. Those of the median series are not enlarged but on the contrary are usually smaller than those of the paired series.

The annuli and the somite limits are well defined, the furrows exhibiting certain constant differences in depth. Somites I and II are united in the reduced prostomial lobe, which may, but usually does not present a faint cross furrow; III and IV are triannulate, the anterior annulus in each case being much the larger. Somite V is triannulate dorsally but the furrow $a1/a2$ is faint and becomes obsolete on the ventral side. There is a very gradual deepening of the furrow $a1/a2$ on the succeeding somites, but VI to XXIII or sometimes

XXIV may be considered to be fully triannulate, as this furrow, though not so deep as the others, is complete. The first annulus (*a1*) is always more closely united with the second (*a2*) than is the third (*a3*). The furrows correspond closely on the dorsal and ventral surfaces. Somite XXIV is usually simpler, owing to the incompleteness of the furrow *a2/a3* toward the mid dorsal region. XXV is biannulate at the margins only, the furrows disappearing mesiad; XXVI and XXVII are normally uniannulate.

The small, pore-like mouth is in II. The salivary glands are compact and with a median lobe. As usual in this genus there are seven pairs of large spreading gastric cæca, in this species extensively developed and reaching almost to the margins of the body as fine lobes more numerous than in any other Minnesota species. The last pair is the largest and reflexed as far as somite XXII.

Small male and female orifices are located in the furrows XI/XII and XII *a2/a3* respectively. The testes are six pairs, the sperm sacs long but closely and complexly folded in somites XI and XII by the sides of the atrium.

The coloration is very rich and striking but extremely variable. The ground color of the dorsum is dull green, olive green or brown, marked with bright yellow which may replace the ground color very extensively. Usually the yellow is confined to the following regions: —A continuous or interrupted longitudinal median band which widens and narrows alternately at intervals of about three somites, regular marginal spots covering the intervals between the successive neural annuli, and large irregular blotches constituting an intermediate series which often become confluent with one another or with the marginal spots or both. The ventral surface is longitudinally striped with light and dark the whole having a peculiar bluish or purplish reflection. Dorsal integuments rather opaque.

Habits—Living chiefly as a parasite upon the snapping turtle on whose blood it feeds voraciously. The geographical range of this species is largely determined by that of its principal host. As the snapping turtle is an important article of commerce this leech is very well known and is reported from all parts of the United States. Its habits are too familiar to require description though it is not so widely known that the species also lives a free life particularly when carrying eggs or young and feeds on aquatic worms etc.

Placobdella rugosa (Verrill) Moore.

(Plate I, fig. 6, 9)

Clepsine ornata var. rugosa Verrill (1874)
Placobdella rugosa Moore (1901)

Description—*Placobdella rugosa* is a large leech, nearly or quite equalling *P. parasitica,* although the great majority of examples met with average considerably smaller than that species. In form it is even more depressed, starving individuals being scarcely thicker than a card, very broad and leaf-like. The head is essentially similar to that of *P. parasitica* but as this leech does not extend itself as fully as that it is seldom seen in the distinctly expanded state. The caudal sucker is large and elliptical rather than circular, the antero-posterior diameter being slightly greater than the transverse. An important characteristic is the presence of numerous large rough cutaneous papillæ on the dorsum. The principal ones are constant in arrangement but the number of smaller ones is quite variable. Most characteristic and conspicuous are five on each neural annulus, median, supra-marginal and intermediate in position and forming five longitudinal series as far caudad as somite XXIII, posterior to which the median papillæ become greatly reduced in size and overshadowed by paramedian papillæ in line with the dorso-median sensillæ. On *a1* the papillæ are all relatively small while *a3* bears some of large size inferior only to the largest on *a2*. The integument is translucent.

Somites I and II are uniannulate and always distinctly separated; III is biannulate with a faint furrow usually discernible across the larger anterior annulus, on the posterior division of which are seen the small compound eyes, often included in a common pigment mass. Somite IV is triannulate dorsally but *a1/a2* is less distinct than the other furrows; V is triannulate dorsally, biannulate ventrally. The fully triannulate somites are VI to XXIII inclusive, and this species shows in a much less convincing way the transitional steps between biannulate and triannulate somites. In all of the complete somites a noteworthy feature is the lack of alignment between the dorsal and ventral furrows, as a result of which *a2* is the longest annulus dorsally but the shortest ventrally. Of the posterior simpler somites, XXIV is triannulate dorsally with *a3* of very much smaller relative size and incompletely separated

from *a2* on the ventral side, XXV and XXVI are wholly or partially biannulate and XXVII uniannulate.

The alimentary canal is nearly as in *P. parasitica* but the compact salivary glands have no median lobe and the divisions of the gastric cæca, although long, are less numerous. The reproductive organs are essentially similar in the two species, with the sperm sac, epididymis and ductus ejaculatorius compactly folded in somites XI and XII.

Owing to the numerous papillæ and the translucency of the skin the colors are a somewhat confused mixture of light and dark browns, yellows and greens, based upon a fundamental pattern similar to *P. parasitica* and consisting of a variegated brown ground with light intermetameric marginal spots, a median dorsal light stripe interrupted by short dark brown or brownish green longitudinal lines, which sometimes unite into a continuous dark line, and numerous small light yellow or green spots corresponding to the papillæ and sensillæ. The ventral surface is plain gray or light brown without longitudinal stripes.

Habits—*Placobdella rugosa,* the rough leech, is a very frequent inhabitant of streams and ponds, where it may be found clinging to the under side of stones and floating wood, especially during the late spring and early summer. At other seasons they are sometimes found upon aquatic turtles upon whose blood they in part subsist. Leeches of this species are sluggish and when exposed in their resting places press the flat body closely to the stone or log, whose colors they so closely simulate, and trust to this protective resemblance to escape detection, rather than creep actively away in the manner of many other species of allied leeches. The close resemblance to surroundings is much enhanced by the fact that particles of mud adhere to the mucous and rough papillæ. Furthermore the leeches may partially bury themselves in the bottom sediments. They seldom swim and when thrown into the water roll up and sink passively to the bottom, upon reaching which, they creep to a place of concealment in a most deliberate fashion.

So far as has been actually observed no other food than blood is taken though it seems probable that the juices and even the solid parts of small aquatic invertebrates may serve the same purpose, as is certainly the case in the nearest ally of this species.

The large chitimoid spermatophores may be observed as frequently and easily as those of *P. parasitica* which they closely re-

semble in form and mode of fixation. The eggs are very numerous and are fixed lightly to the ventral surface of the body covered by a delicate mucoid membrane. During the period of incubation the parent leech attaches itself firmly and is very loath to leave its resting place. If, under such circumstances, force be used the leech holds tenaciously by both suckers to its support and curls the lateral margins of the body in such a manner as to enclose the eggs or young. As a result of a struggle to remove the brooding leech the eggs are generally detached and are then sometimes found to be adherant to the stone or glass of the aquarium against which they have been pressed. When forcibly removed from the eggs the leech will usually seek and return to them.

Placobdella montifera nom. nov.

(Plate I, fig. 5, Plate II, fig. 10)

Clepsine papillifera var. *carinata* Verrill (1874)
Not *Clepsine carinata* Diesing (1858)
Hemiclepsis carinata Moore (1901)

Description—The size is moderate, never approaching the maximum of the two species of the genus already described. In addition to the widely expanded discoid head, which is quite characteristic, the form is more slender and less flattened and foliacious than usual in the genus. The posterior sucker is large, circular, rather freely pedicillate and minutely denticulated about the margins. The oral sucker also possesses unusual mobility, has a prominent free margin all around and a narrow unsegmented border. The capacity for extension and contraction exceeds that of either *P. parasitica* or *P. rugosa*. The dorsum bears three rows of very large conical papillæ situated on the second and third annuli of each somite for the greater part of the body as far as somite XXI. These are borne on the crests of three prominent nearly continuous ridges. On somites XXII to XXVI the three tuberculated keels cease and are replaced by a pair of large paramedian papillae on each somite.

The anterior somites are better developed than in the closely related species, no doubt in correlation to the formation of the distinct head, into which the first five enter. The first two are each faintly biannulate, III is distinctly biannulate, with *a1* obscurely separated as a small anterior ring, behind which is situated the pair of small eyes. There are seventeen completely triannulate somites (VI to

XXII inclusive). In the neck-like constriction between the head and body is a peculiar double annulus which is interpreted as V *a1*. In the complete somites the three annuli increase in length caudad and *a3* is partly cut into two by marginal furrows. Somites XXIII and XXIV are triannulate at the margins only, the third annulus of each being the least developed, and the furrow XXIV *a1/a2* deficient mesially. The two following somites (XXV and XXVI) are further simplified in the direction indicated in XXIII and XXIV. They are incompletely biannulate with only traces of *a2/a3;* XXVII is uniannulate. Three well marked post-anal annuli form the narrow portion of the sucker pedicle.

The mouth is small in somite II; The proboscis is long and slender and the œsophagus of about equal length. There are the usual seven pairs of capacious gastric cæca divided into numerous lobes which reach almost to the margins of the body; the first sends a long anterior lobe forward into somite XI and the last reaches from XIX to XXIII. The salivary glands are compact and rather small.

While conforming in every important feature to the general plan characterizing the other members of this genus, the reproductive organs are somewhat peculiar in the shorter and more loosely folded sperm sacs.

The color is generally a dull greenish gray or pale olive brown with an interrupted dark green or brown median dorsal line, a series of obscure light yellow marginal spots or a marginal yellow border, more or less interrupted on the neural annuli, and spots of the same color, often including green flecks on the papillæ. A deeply pigmented green and brown spot marks the otherwise pale colored head. The ventral surface is plain.

Habits—This very interesting keeled leech exhibits little of that marked gregariousness which is common to most other members of the family. It is met with far more frequently singly than in company. As a parasite it devotes itself especially to frogs and, when they frequent the water during the breeding season, to toads.

It also habitually enters the shells of living mussels, though it is not known definitely that it feeds upon their soft tissues. Meadow brooks and swamps adjacent to the shores of lakes and ponds are its favorite haunts, where it lives among water plants and beneath stones as well as upon the bodies of frogs. Nothing is known of the breeding habits beyond the bare facts that spermatopores are deposited in early spring and that the young are carried.

Although Verrill was the first to describe this species, his name, which I used in a former connection when the species was erroneously referred to *Hemiclepsis,* is preoccupied by *Clepsine carinata* Diesing (1858) which is unquestionably a *Placobdella.* The name *montifera* is therefore proposed as suggestive of the resemblance of the carinæ to conventional mountain ranges.

Placobdella Pediculata Hemingway.

Plate II, Figs. 13-18.

Placobdella pediculata Hemingway, American Naturalist, Vol. XLII, 1908, pp. 527-532, figs. 1-3.

Description*—Like *Placobdella parasitica* and *P. rugosa* this species reaches a large size, though no specimens quite equalling the largest examples of these, its allies, have been seen. Judged by the poor state of preservation of the few adults that I have examined it is in life soft-bodied and more than usually contractile. All of these specimens—numbering six—are gorged with blood and in this state are thick and hard in the region of the body occupied by the gastric cæca. All are strongly contracted and have the very characteristic pyriform outline and strongly convex dorsum evident in the figures, but the most striking peculiarity is the abrupt contraction and attenuation of the posterior segments to form a narrow pedicle supporting the caudal sucker, which, consequently, stands out freely exposed behind the wide posterior part of the body in a most characteristic manner. Hemingway has made the interesting discovery that this condition arises in the course of individual development and does not exist in young leeches one centimeter long, which consequently differ less obviously than do the adults from related members of the genus. The oral sucker, as far as can be determined in its contracted state with the lip inrolled, has the same structure as in *P. parasitica.*

The skin is perfectly smooth, without a trace of cutaneous papillæ; and only a few obscure segmental sensillæ and Bayer's scattered sense organs, the latter chiefly near the margins of the

*This description is printed substantially as originally prepared for this report but several important additions and corrections, for which I am indebted to Hemingway's paper, are either bracketed or specifically credited to that source.

body, were detected. Undoubtedly suitably preserved material would exhibit the sensillæ typically distributed and essentially as they occur in related species. Eyes are very difficult to detect in surface views of preserved adults but small pigment masses occur at III/IV in the same position as in *P. parasitica* and (distinct eyes appear at III/IV in the young). However, it has not been determined whether the eyes are simple or aggregated.

In spite of the obscurity due to great and often unequal contraction of the annuli a careful analysis of the external morphology shows that, except for the caudal peduncle and an apparently greater simplicity of corresponding anterior segments of *P. pediculata,* the structure is essentially as in *P. parasitica.* In respect to the annulation the condition existing in young leeches must be accepted with some caution as the somites become increasingly complex with growth and age. The annulation of somites I to IV of adults is unknown but in the young (I and II contain each but a single annulus and III and IV are biannulate). Somite V is biannulate dorsally but ventrally the furrow fades away toward the median line; VI is triannulate at the margins but the furrow a1/a2 is incomplete above and even more so below. Somites VII to XXIII (or XXIV) are triannulate but the furrow a1/a2 is incomplete medially on the venter of both VII and VIII and on most of the succeeding somites is less marked than either a2/a3 or the intersegmental furrows. On anterior somites, and, to a less degree on the posterior a3 is slightly longer than a1 or a2.

The annulation of the post-anal somites, constituting the caudal peduncle, is irregular and somewhat puzzling on the adult specimens, but here also most of the somites, while very short, appear each to be made up of three small annuli of varying size and incompletely defined limits. Figure 16 represents accurately the exact arrangement of the furrows. On young specimens (somite XXIV is triannulate, XXV, XXVI and XXVII are all biannulate but a1 of somite XXV is partially divided and a1 of both XXVI and XXVII is larger than a2). Somite XXIV, which immediately succeeds the anus, is the last segment of the body proper and on the contracted specimens its posterior border forms a fold which envelopes the contiguous portions of the narrow peduncle. The latter continues to taper to the sucker, to the middle portion of which it is strongly attached for rather more than the posterior half. The posterior sucker is large, circular and directed

strongly ventrad. (The disc is composed of somites XXVIII to XXXIV.) The few nephridopores that are visible are situated as in *P. parasitica.*

The mouth is very small and is situated far forward near the anterior rim of the sucker in somite II. As in related species the proboscis is slender, the œsophageal glands compact and the stomach provided with seven pairs of large cæca reaching nearly to the margins of the body. The cæca are less deeply divided and simpler than those of *P. parasitica,* each of the first six pairs presenting only two or three rather short lobes. The intestine reaches to the posterior part of somite XXIV or even beyond and then bends abruptly forward toward the dorsum as an extremely narrow rectum to the anus situated at XXIII/XXIV. The forward curvature of the rectum and the anterior position of the anus are unique features in the family.

The reproductive organs are essentially similar to those of *P. parasitica.* The male and female external orifices are situated respectively at XI/XII and XII a2/a3. Six pairs of testes are crowded between the bases of the gastric cæca. The large sperm sac and ejaculatory duct of the vas deferens form a compact snarl in somite XII in the immediate neighborhood of the atrium.

In addition to the type specimen taken by Professor Nachtrieb from the isthmus of a sheepshead at Lake Pepin, the writer has also examined specimens in the collection of the Illinois State Laboratory of Natural History taken from the same host at Henry and Peoria, Illinois.

Habits—Hemingway gives the following account of what is known concerning the interesting habits of this leech:—

Placobdella pediculata appears to be a true fish parasite, having been found only in the gill chamber of the freshwater sheepshead (Aplodinotus grunniens), the posterior sucker of the leech being deeply imbedded in the side of the isthmus or shoulder. In the case of young leeches which have not been long attached, the depression caused by the posterior sucker is comparatively shallow, being a mere external depression in the inflamed tissues of the fish. As the attachment continues the inflamed tissues of the host grow up like a collar and close in around the leech's body in front of the sucker. This closing in of the inflamed collar presses upon the body of the leech, narrows it to a slender peduncle in front of the sucker and incidentally crowds the sucker down into the tissues of

the fish, so that, in time, this depression may reach into the underlying muscles of the host to a depth of half an inch or more and have an opening of about a quarter of an inch or less in diameter. The bottom of the depression has a larger diameter. Figure 5 of plate C represents the positions of three depressions from which the leeches have been removed, and figure 6 represents one of the depressions cut in two lengthwise.

These leeches are capable of becoming greatly contracted and when one is disturbed it draws back until it appears as a mere brownish pyriform knob which entirely covers the place of attachment.

The burying of the posterior segments in the tissues of the host has brought about an interesting structural change, so that we find the anal opening shifted forward to a position between somites XXIII and XXIV instead of between somites XXVII and XXVIII as in the other members of the genus. It is noticeable that, while the young leeches whose posterior portions are not yet deeply imbedded have the characteristic position of the anus (XXIII/XXIV), the outline of the posterior part of the body is still a regular curve showing none of the pedicular characteristics so pronounced in the older individuals. The posterior sucker, however, is very strongly developed even in those not more than a centimeter long.

Practically nothing is known of this leech separate from its host, but it seems possible that a part of its existence may be spent elsewhere. During September, 1903, I examined several thousand specimens of the sheepshead from Lake Pepin and found only three isolated leeches, each about a centimeter in length. The posterior sucker, while imbedded in the tissue, was not sunk in deeply and so had not produced the characteristic peduncel. They were evidently young ones which had recently attached themselves to their hosts and were gradually sinking the posterior sucker into the host's flesh. As full grown specimens, deeply imbedded, were found in the same locality during August of 1899, at least some of the adults must remain with their hosts during the summer and probably thruout the year.

Placobdella hollensis (Whitman)

(Plate II, fig. 11)

Clepsine hollensis Whitman (1892)

Description. This very distinct species will retain a permanent interest for zoologists because of its having furnished the material for Whitman's classical analysis of the nervous system of the leech. Its place in the fauna of Minnesota is established by several examples taken in Poplar Lake near St. Paul and sent to me with other leeches by Prof. Henry L. Osborn.

The form is very similar to *P. parasitica* but the present species is a very much smaller leech, a length of from one to one and one-half inches being about the usual size, though individuals reaching two inches in extension have been observed. The most obvious external characteristic is found in the eyes. As in other species of *Placobdella* a pair of large contiguous compound eyes exists in somite III with their bases resting in a conspicuous pigment mass and their principal visual component directed forward. But unlike the other species described this pair is succeeded by an indefinite number of pairs of much smaller eye-like organs which Whitman has shown to be the modified dorso-median sensillæ, which possess a diminishing number of visual cells in each successive pair toward the caudal end, and gradually pass into the ordinary sensillæ. Superficially each appears as a small clear or whitish area anterior to which more or less black pigment is accumulated in the form of an irregular cup. The first pair (on IV) is decidedly prominent and those on V and VI are also quite conspicuous and eye-like. At first sight, therefore, this might be described as an eight-eyed leech, with the first pair of eyes directed forward, the remaining three, which are smaller and simple, backward. More careful examination shows that the same features exist in a lessening degree in several additional pairs of the dorso-median and some of the dorso-lateral sensillæ as well, making it quite impossible to determine just where the visual possibilities of the sensillæ cease. All of the sensillæ are very distinct, rendering this a very favorable object for study on this subject.

The back is more or less roughened with small sense organs and a few larger round smooth papillæ. The latter correspond to the largest papillæ of *P. rugosa* and are most prominent posteriorly. In the Minnesota specimens they begin on the neural annulus of

VIII and by somite X present the following typical arrangement: The neural annulus bears a median one and a pair just mediad of the dorso-lateral sensillæ. *A3* bears a pair directly in line with the dorso-median sensillæ and *a1* a smaller median one.

This species exhibits the same gradual development of the biannulate and triannulate somite as *P. parasitica* and consequently presents the same difficulties in the application of a formal descriptive terminology. Somites I and II may be considered as uniannulate, III, IV and V as biannulate, VI as transitional and VII to XXIV or XXV as triannulate; XXVI and XXVII exhibit partial subdivision only at the margins. The complete somites of the middle region of the body show the same tendency of the sub-division of *a1* and *a3* into secondary annuli that is exhibited by *P. rugosa*. In the internal anatomy a considerable number of minute differences between this species and *P. parasitica* have been observed, but the general and obvious structure of the alimentary canal and reproductive organs of the two species is essentially alike.

The colors as described from living eastern representatives of the species are rather characteristic. The dorsum is generally a light olive green varigated with brown, pale yellow, and colorless areas. The head end lacks pigment almost entirely except what is concentrated about the eyes and in the transverse bands on the neural annuli. This light area extends caudad for some distance as a median vitta between the pairs of small eyes. On the neural annuli it is usually interrupted by the transverse bands of interocular pigment between which it is flanked by dark cloudings which more posteriorly takes the form of a pair of dark longitudinal bands just mediad of the dorso-median sensillæ. At about somite X and thence caudad, the median vitta and its dark flanking bands are transformed into a chain-like pattern consisting of alternate dark bars and elliptical rings with light centers, the former extending over about two somites and the latter one somite, there being about five of each. Posteriorly an elongated light median area represents several of the rings coallesced.

The larger cutaneous papillæ are of a light yellow or cream color and those of the most medial neural series interrupt the dark bands described above. A similar yellow color occurs along the margins, alternating in blocks with the green ground color. In many specimens narrow bands of dark pigment extend across the entire dorsum of the anterior neural annuli and less frequently all or nearly all of the sensillæ are flanked on the medial side by brown or black pigment. The ventral surface is nearly plain.

Habits. This very interesting leech bears the same relation to the smaller fresh water tortoises that *P. parasitica* does to the snapping turtles and other large species. Not every tortoise is parasitized but as a rule several of the leeches are found associated together on each one so affected. The species also frequently occurs on the under side of floating wood in ponds inhabited by tortoises. In its movements it is more active than other species of *Placobdella* and swims with much greater facility than any other, not excepting *P. montifera.* The spermatophores and breeding habits are very similar to those of *P. parasitica* and *P. rugosa.*

Genus **Hemiclepsis** Vejdovsky.

Form variable, usually rather wide and moderately depressed; tissues soft and almost œdemous, translucent. Suckers as in *Glossiphonia.* Eyes usually four pairs, in longitudinal series near the median line. Cutaneous papillæ few and low. Pharyngeal salivary glands diffuse; gastric cæca nine or ten pairs, branched. Genital pores as in *Glossiphonia,* but sometimes farther apart. Chiefly free-living.

*Hemiclepsis occidentalis (Verrill)

(Plate II, fig. 12.)

Clepsine occidentalis Verrill (1874).

Description—This rare and very interesting leech is represented in the Minnesota collection only by a batch of young, evidently removed from the parent which carried them, and is consequently described from specimens received from other localities, though the anterior end of one of these young is represented in the figure. The leech is of moderate size, about one and one-half inches being the limit in extension. In life it is of a rather slender form, broadly rounded anteriorly where there is no definitely expanded head, moderately depressed but rather thick at the margins posteriorly and with a very large caudal sucker. A noteworthy feature which separates this from every other species described in this paper is the peculiar transparency and gelatinous consistency of the body.

There are four pairs of large conspicuous eyes, which cannot be mistaken for the much smaller ones of *Placobdella hollensis.* They are situated on somites II to V respectively; the first pair is the

*The name **Protoclepsis** Livanow (1902) proposed for this group is preoccupied by **Protoclepsine** Moore 1898.

smallest and very close together or even in actual contact, the others are successively more distant and the third pair is the largest. The first and second are directed forward and outward, the third and fourth backwards and outward.

The upper lip is very mobile and in preserved examples is almost invariably curled into the cavity of the sucker. The small mouth is far forward in somite II. Genital orifices occur at the positions so frequent in the *Glossiphonidæ*, the male at XI/XII, the female at XII *a2/a3*. In one specimen the male bursa is everted in the form of a short conical penis, this being the only species of the family described in this paper in which such an organ is present.

Besides the numerous scattered sense organs which roughen the skin there are three pairs of low dome-shaped papillæ on each neural annulus except at the anterior end of the body. Apparently these bear the dorso-median, dorso-lateral and dorso-marginal sensillæ, the first of which are separated by about one-fourth of the width of the body.

With the exception of somites X, XI and XII, on which they cannot be detected nephridiopores occur on *a2* of every somite from VIII to XXV. Very little is known of the internal anatomy of this species but quite enough to establish its position as a member of the genus. The proboscis is very short and is succeeded immediately by a very short œsophagus and a long stomach which bears nine pairs of branched cæca, two of which are anterior to the reproductive orifices and the last reflected in the usual manner. The muscular system is very peculiar in the wide intervals which exist between the bundles of muscle fibers.

The color of preserved specimens is a translucent grayish green, the dorsum being rather thickly spotted with cream yellow, the largest spots corresponding with the six series of papillæ described above.

The annulation presented in figure 12 should not be taken as fully characteristic of the species as it exhibits the somites in the undeveloped biannulate or nearly biannulate condition which is observed in the young of all species. With a more pronounced development of the furrows between *a1* and *a2* it would, however, be diagnostic. In the adult somite I is a distinct but small preocular lobe, II nearly and IV fully biannulate. A very interesting feature, which is found in all of these young and in the few adults which I have studied, is that somite V is shorter and much less elaborate than IV. Somite VI approaches the triannulate type very closely and VII to XXIV inclusive

are completely triannulate; their annuli and furrows are all equal. Finally XXV is biannulate, XXVI biannulate or uniannulate and XXVII uniannulate.

It is not at all certain that this is really Verrill's *Clepsine occidentalis* as at least two and perhaps three other species of eight-eyed glossiphonids are found in this country.

Habits—An eastern species of *Hemiclepsis* has been observed in the living state and it is probable that the habits of the form described will not depart much from this. The most striking peculiarity is its remarkable activity. No other members of the family creep with anything approaching its speed. In creeping the caudal sucker is brought forward into actual contact with the oral sucker and the movement is repeated with great rapidity. So far as has been observed the species is entirely sanguivorous, the blood of frogs being taken while worms and snails are refused. The European *H. tessellata* is known to attack water fowl and to be transported while attached to their legs or within the nasal chamber which it occasionally enters. Fertilization takes place by means of spermatophores attached to the skin, but egg laying has not been observed.

Family Ichthyobdellidæ.

Leeches of small, medium or large size. Form much varied; short and stout or elongated and slender, terete or depressed, usually more or less divided into a narrower anterior and an expanded posterior region. No distinct clitellum, but diffuse clitellar glands abundant. Segments smooth, or more rarely papillated, often provided with lateral pulsating vesicles or gills on a certain number of segments. Complete somites with from 2 to 14 annuli, greatly varied in proportions. Both oral and caudal suckers usually large and deep and more or less prominently set off on pedicles. Eyes 1 to 3 pairs widely separated on posterior part of head, often absent. Eye spots often on caudal sucker. Mouth and proboscis as in *Glossiphonidæ;* stomach straight and usually simple, only rarely with lateral cæca, one pair of large posterior gastric cæca, variously and sometimes completely united. Genital orifices much varied in position according to the number of rings per segment. Testes usually five or six pairs, the sperm ducts relatively short, the epididymis and ejaculatory duct not much convoluted, ending in an atrium that may be simple or more or less complex; no filiform penis. Ovisacs paired or united into one, pyriform or globular, their ducts simple. Eggs laid in usually stalked

cocoons. Chiefly semi-permanent parasites on fishes, sometimes on crustaceans. Nearly all are marine. *Piscicola* and closely related genera only are found on fresh water fishes.

Genus Actinobdella Moore.

Rather slender and elongated, moderately depressed or half round. Oral sucker slightly developed; caudal sucker large, deep, and provided with a circle of numerous marginal papillæ and glands. A few dorsal papillæ, some median. Complete somites of six unequal rings. Eyes, one pair on III, united. Pharyngeal salivary glands diffuse; gastric cæca seven pairs, branched. Genital orifices separated by four rings; sperm ducts lacking long loops, moderately compact. Small blood-sucking leeches, probably parasitic on fishes.

Actinobdella inequiannulata Moore.

(Plate III, fig. 19, 20.)

Actinobdella inequiannulata Moore (1901)

Description—The collections from Lake Pepin included an example of this very interesting species, the second one known, which enables me to confirm and extend, and in some particulars to correct, the original description. This additional knowledge renders more evident than before the position which *Actinobdella* occupies on the border between the two families of *Ichthyobdellidæ* and *Glossiphonidæ*, in fact the mere numerical weight of its characters as now known point rather toward an alliance with the latter. As I hope soon to have sufficient material to permit a thorough anatomical study the discussion of its zoological position can best be postponed. The Lake Pepin specimen measures 12 mm. in length and has nearly the form of the type except that the middle region of the body is somewhat widened. The following description is nearly a transcript from the original with such changes and additions as further knowledge necessitates.

The form is slender and depressed throughout, with the dorsal surface convex, the ventral flat and the margins sharp. The breadth is nearly equal or somewhat greater in the middle region, but contracts suddenly at the posterior end to constitute the narrow pedicle of the conspicuous caudal sucker, and at the anterior end tapers gently to the broadly rounded upper lip.

There is no conspicuously expanded anterior sucker or head as in typical ichthyobdellids, but this end of the body is formed exactly

in the fashion of a glossiphonid. Four somites of simple structure enter into its composition, the posterior ventral rim being formed by the fourth and fifth somites in that region largely coalesced. On the middle of somite III is situated the single pair of small eyes conjoined in a single median pigment mass and looking forward and outward. Some detached pigment cells occur caudad and lateral of this position.

Most remarkable of all of the external features of this leech is the posterior sucker. It is much wider than any part of the body, largely free around its entire circumference and supported by a narrow central pedicle. The ventral surface is very deeply cupped and the rim somewhat contracted, making the diameter of the opening somewhat less than that of the internal cavity. From the internal face of the sucker, a short distance back from the sharp margin, spring about thirty (thirty in one, twenty-nine in the other, specimen) slender finger-like papillæ which project more or less freely beyond the margin. Owing to their contractile nature they vary in length and diameter but when extended the longest are about .4 to .5 mm. in length and about .1 mm. in diameter. Each one contains an axial gland duct or group of ducts surrounded by a sheath of muscle fibres which spring from the muscular ridges passing radially down the inner face of the sucker. The gland ducts arise from a circle of glands which appear as a circle of whitish spots arranged around the sucker about midway between the margin and the pedicle and which raise the outer surface into a slightly marked encircling ridge.

A median series of rather prominent conical papillæ with the long diameter of their elliptical bases directed in the longitudinal axis of the leech occur on the large annuli *b3* and *b5*. In the Lake Pepin specimen these papillæ begin on VIII *b5* and continue to XXVI *b3;* in the type they are distinctly developed only on the somites XI to XXV inclusive. In the new example also traces of supra-marginal and intermediate series of papillæ are found on the somites of the middle region. Segmental sensillæ are very beautiful and regularly shown in this specimen on all of the somites and both dorsally and ventrally. The position of those found in the type and shown in the figure of that specimen is confirmed and in addition the presence of supra-marginals and of six ventral series is established. Thus it will be seen that the sensillæ have the arrangement characteristic of the *Glossiphonidæ*. Well developed rings of small sense organs are visible on annuli *b2, b3* and *b5* of each of the complete somites and are more or less discernible on all primary annuli and more comprehensive divisions throughout the body.

Somites I, II and III are each uniannulate; IV is also practically uniannulate but shows some signs of division above in the Pepin example and below is largely united with V. The latter, together with VI and in the type, VII also, is biannulate, an interesting feature being the rather larger size of second annulus. Somite VIII is quadriannulate, being composed of *a1/a2/b5/b6,* the latter two being very narrow.

Somites IX to XXV inclusive may be regarded as complete, but some individual variations are exhibited and especially the first two and the last are transitional. In the original specimen the complete somites are sexannulate, the full number of secondary annuli being developed, but of very unequal size. Two annuli, (*b3* and *b5*) are enlarged, the latter most so, and bear the dorsal cutaneous papillæ, and the former the metameric sensillæ as well; *b1*, *b2* and *b6* are about equal and *b4* is the smallest of all. The small annuli *b1*, *b4* and *b6* appear to be entirely unadorned, while *b2* like the large papillated annuli exhibits a circle of sense organs.

The conditions in the new specimen are essentially similar, but the somites are somewhat further elaborated. Somite VII is triannulate rather than biannulate, VIII has the small annuli *b1* and *b4* rather distinctly separated and there is a very strong tendency in the anterior part of the post-clitellial region toward the splitting off of small additional annuli from the anterior margins of the enlarged annuli *b3* and *b5* which leads toward the production of octannulate somites. A trace of this is indicated in some of the somites of the type specimen as is shown in the figures.

The remaining pre-anal somites XXVI and XXVII are typically triannulate. Two post-anal annuli are present in the type and four in the new specimen.

A few anatomical facts gleaned from the Lake Pepin specimen, though very fragmentary, are nevertheless of great interest; for it will be seen that in all essentials the alimentary canal is constructed on the plan prevalent in the *Glossiphonidæ*. The position of the mouth at the extreme anterior margin of the oral sucker in somite II, or perhaps even in I, is paralleled in the *Ichthyobdellidæ* only in *Notostomum* (Levinsen 1881). The probscis is long and slender, reaching when retracted, from VI to X, at its posterior and receiving apparently three pairs of slender ducts from the salivary glands. The latter consist of very numerous small gland cells scattered diffusely all through the preclitellal somites as far as the head. The œsophagus

is slender and distinctly differentiated from the stomach. At least six pairs of well marked, long and slender gastric cæca are developed, arising in somites XIV to XIX inclusive. Unfortunately they are empty and shrunken and on account of the numerous gland cells which fill the region difficult to see clearly, but they are certainly somewhat branched and extend far toward the margins of the body. Those of the last pair are long and reflected and extend as far as XXII, lateral branches arising in each intervening somite in the characteristic glossiphonid fashion. The intestine is a narrow tube which gradually tapers to the anus and shows the differentiations usual in the higher glossiphonids, including four pairs of prominent slender cæca which arise in somites XX to XXII and lie dorsad of the last pair of gastric cæca. The first two are bent forward, enlarged at the end and somewhat subdivided, the third is bent backward and slightly lobulated and the last is simple and directed rather strongly caudad from its origin. The anus is situated at the posterior margin of XXVII, in this case within the limits of that somite.

Very little of value can be made of the internal genital organs. The testes are not certainly discernible. There is a pair of short wide sperm sacs crowded with spermatozoa extending from the posterior limit of somite XIII to a point just abreast of the male bursa, where they pass into the narrower ejaculatory ducts which curve around the anterior face of the bursa toward the median plane and then bend dorsad and caudad to the summits of the prominent nearly spherical prostate cornua. The latter open on each side into the dorsum of the small bursa. The ovaries are enlarged pyriform bodies which lie rather widely separated just caudad of the sperm sacs; from their anterior enlarged ends narrow oriducts pass mesiad and slightly cephalad to the female orifice. The external genital orifices are situated in the positions usual in the higher *Glossiphonidæ*, the male at XI/XII, the female approximately at XII *a2/a3*. Nephridiopores are quite easily distinguishable on the post-clitellal complete somites just anterior to the sensillæ line on annulus *b3* and well mesiad of the margins.

According to the label the Minnesota specimen was colored green during life. It was pumped from the bottom of Lake Pepin. Nothing is known of the habits of this leech.

Genus Piscicola Blainville.

Size small; form slender and elongated, terete or subterete. Both suckers large and explanate, the posterior usually deeply cupped. Complete somites of 12-14 very short tertiary annuli. Sensillæ and cutaneous papillæ very inconspicuous or absent. Eyes one or two pairs widely separated on base of "head". Atrium simple and intestinal cæca nearly completely coalesced. Parasitic on fishes, but often found free.

Piscicola punctata (Verrill).

(Plate III, figs. 21, 22)

Ichthyobdella punctata Verrill (1871)

Description—The usual size of this species is from 15 to 25 mm. long and 2 to 3 mm. in greatest diameter, but the largest examples are capable of extending to a greater length. In extension the body is circular in cross section and very slender, widest at the beginning of the posterior third. When contracted the distinction between anterior and posterior regions of the body is much emphasized and the latter becomes distinctly flattened. Although it has the form characteristic of the genus the head is much smaller than in the well known *P. geometra*.

Only one pair of eyes has been detected in a large number of specimens which have been received from various localities. These have conspicuous pigment cups situated in somite four and consequently correspond to the posterior eyes of *P. geometra* which they resemble also in the fact that they look caudad instead of cephalad as do the first pair in that species. The smaller posterior pair described by Verrill I have been unable to find either in entire mounts or in sections and it is possible that some of the conspicuous pigment cells which are scattered through the head may have simulated eyes in his living specimens.

During life the posterior sucker is widely expanded and hemispherical, but in preserved specimens it is always much contracted and directed caudad. Just anterior to it is the minute anus among a group of small wrinkled annuli.

The genital region (clitellum) is more or less distinctly limited by anterior and posterior constrictions at the furrows IX/X and XII/XIII respectively. In contraction XII may be more or less retracted within the anterior border of XIII and all three of the somites

of this region are of simpler structure than the typical complete ones adjoining. Clitellar glands are greatly developed and form a thick layer just within the longitudinal muscle layer and extending from the clitellum nearly to the anus. They are arranged in four longitudinal bands on each side leaving narrow neural, median dorsal, and lateral spaces clear. The latter are occupied by the lateral vessels which exhibit metameric enlargements in the somites of the posterior region.

Ten pairs of large nephridiopores are present on the latero-ventral region of somites XIV to XXIII inclusive. They lie in annulus *c6*. No especially metameric sensillæ have been certainly distinguished but numerous small sense organs arranged in transverse rows in many of the annuli are present.

Owing perhaps to the different methods by which my material has been prepared the annulation varies in a manner which, combined with its complexity, is very confusing, and a complete analysis has not been reached. Figure 21 Plate III exhibits a case which approximates the most frequently occurring condition, together with the interpretation of somite limits which has been based upon a study of the annuli themselves, the nephridiopores, nerve ganglia and partially of the peripheral nerves.

Complete somites have the full number of tertiary annuli (*c1* to *c12*) developed and in many one or two of these, usually in the cephalic third of the somite, are divided into two, making in the latter case fourteen annuli; but it is in connection with this feature and the simpler somites at the ends of the body that the variability occurs.

Unlike *Actinobdella* the mouth is situated far back in the oral sucker at III/IV or possibly within the limits of IV. The rather short proboscis ends in VIII where it receives the several ducts of the diffuse salivary glands occupying the pre-clitellial region. The stomach is moniliform, constricted into six spheroid chambers occupying somites XIV to XIX inclusive and entirely without lateral cæca. The last one passes into a long capacious unpaired cæcum which shows no apparent traces of its dual origin and extends with slight sacculations to a point immediately beneath the anus. The stomach and cæcum, as might be expected, have a precisely similar histological structure and both have a green color owing to the presence of numerous branched pigment cells in their walls. The intestine arises from the dorsum of the last gastric chamber in XIX by a constricted opening and lies dorsad of the cæcum throughout its length. At its commencement it bears a pair of short wide pouches which project for-

ward. About its middle is a constriction and caudad of this an enlargement bearing another pair of cæca. Smaller cæca may occur between.

There are but five pairs of testes alternating with the gastric sacculations. Very delicate vasa efferentia start at the dorso-mesial side of the testes and then pass forward and outward among the ventral clitellar glands to the vas deferens, a very delicate tube resting on the ventral body walls. Passing ganglion XIV the vas deferens becomes larger and its course wavy and just in front of ganglion XIII expands into a short, wide sperm sac which is looped caudad and, after a constriction passes into a ductus ejaculatoruis of half its diameter and twice its length. The latter becomes very narrow as it enters the thick loose layer of unicellular glands which conceal the median eversible bursa from view. The male orifice is located at XI/XII. The paired ovaries are large elongated simple sacs which even in their much folded condition reach as far caudad as somite XVI. They open at or about XII *a2/a3*.

Verrill describes the colors during life as "translucent greenish, with a pale median dorsal line and with minute black specks arranged in transverse bands; along each side are eight light spots, alternating with the dark punctate bands." The black specks are branched pigment cells which are scattered through the integument with singular regularity. Large individuals become more opaque owing to the great development of clitellar glands.

Habits—This is our commonest fresh water fish leech. It is common in the ponds and lakes of the northern states and the Mississippi Valley and is especially abundant along the Ohio shore of Lake Erie. It lives upon the exterior of the body of various species of small fishes feeding upon the mucous which covers the surface as well as upon their blood. It appears to be in no way injurious to its hosts. Many examples may also be found living among water plants to the stems of which there is good reason to believe its stalked cocoons are attached.

Family Hirudinidæ.

Leeches mostly of large size, more or less elongated, with thick, little depressed bodies. A well-developed zonary clitellum in most species during the breeding season. Oral sucker forming lips surrounding the large mouth; caudal sucker rather small or well developed, discoid. Complete somites usually of 5, rarely of 3 or 7, an-

nuli. Eyes usually 5 pairs, forming a marginal arch on somites II to VI. Metameric sense organs usually conspicuous colorless spots on the neural annuli, 6-8 above and 4-6 below. Cutaneous papillæ small or absent. Mouth large, occupying entire oral sucker; pharynx not protrusible, usually preceded by three compressed, muscular, toothed jaws, one dorsal and two ventro-lateral, the former alone, or all three sometimes absent. Stomach with a single posterior pair of simple cæca, or provided with one or two pairs of cæca in each segment; no intestinal cæca. Genital pores variable, the male usually on XII, female on XIII and usually separated by 5 annuli; associated copulatory glands may be present. Testes sacs usually 10 pairs belonging to somites XIV-XXIII. Genital ducts complex, the male terminating in an unpaired atrium with prostate gland and a usually filiform penis. Ovisacs 1 pair, small pyriform, opening into an unpaired oviduct terminating in a long vagina. Copulation occurs, during which the penis of one individual implants spermatophores in the vagina of the other. Eggs enclosed in vesicular or spongy chitinoid cocoons deposited in damp earth. Fresh water or more rarely terrestrial leeches, which are voracious blood suckers or predatory destroyers of weaker invertebrates. Mostly active swimmers.

Genus **Macrobdella** Verrill.

Size large. Dorsum marked by metameric red and black spots. Jaws prominent each bearing numerous small teeth in a single series; gastric cæca very spacious, two pairs to each somite from X to XVIII. Genital orifices separated by from 2½ to 5 rings, followed by the two pairs of copulatory gland pores, which form a quadrate figure opening in the furrows XIII/XIV and XIV *b1/b2;* penis short and conical; atrium and vagina both short, globoid. Active blood-suckers, attacking vertebrates.

Macrobdella decora (Say) Verrill.

(Plate IV, figs. 24, 25; Plate V, fig. 38)

Hirudo decora Say (1824)
Hirudo decora Leidy (1868)
Macrobdella decora Verrill (1872)

Description. *Macrobdella decora,* the American medicinal leech, reaches a length of eight to ten inches and a breadth of three-quarters of an inch, but the examples most frequently met with are much smaller than this, while the largest may occassionally exceed this size.

The body is depressed throughout, more so than in any native species of the family and the margins are sharp. During life, however, the body is very soft and assumes a great variety of attitudes and shapes.

The oral sucker is a powerful organ provided with a rather wide unsegmented and very mobile border which very materially increases its extent. Anteriorly a distinct median emargination corresponds with a deep ventral sulcus which divides the upper lip and is flanked by a pair of somewhat shallower sulci. The upper lip can be folded into the buccal chamber and almost concealed by the lateral lobes which close beneath it. As usual in the family there are five pairs of eyes, larger in this species than in the species of *Hæmopis*. Their arrangement is sufficiently indicated in the figure. The posterior sucker is large, broadly attached and circular.

When fully developed the clitellum is firm and thick and extends over eighteen annuli, from X *b5* to XIV *b2*, but it is seldom so well marked nor so extensive. In the ordinary condition the male pore appears as an opening of considerable size in the furrow XI/XII, into which the surrounding regosities converge. When these inflected parts are everted they form a more or less prominent conical penis which reaches a length of about three millimeters when fully protruded. In this condition it is supported almost entirely on annulus XII *b1* which has greatly encroached on the preceeding annulus in the middle region. The female orifice is a small opening with rugous margins situated at XII/XIII or XIII *b1*.

Very characteristic of the genus are the copulatory glands, which form conspicuous masses occupying a large part of the middle region of the floor of somites XIII and XIV. Their external openings are four in number, arranged at the four angles of a nearly square figure, the first pair opening in the furrow XIII/XIV and the second in the furrow line XIV *b1/b2*. Surrounding each of the pores is a slightly tumid region extending over the contiguous halves of the two annuli between which the pore lies. When fully developed the four tumosities are separated only by shallow furrows and together form a conspicuous rugous quadrate area extending over the posterior half of XIII *b6*, the anterior half of XIV *b2* and all of the intervening annulus. Longitudinal and transverse diametral furrows divide it into quarters.

The surface of the body of this species is quite smooth and free from papillæ, although more or less roughened in some preparations by the scattered sense organs. Nephridiopores and sensillæ have the

customary disposition. The latter can be very favorably studied on the dorsal surface but are difficult to distinguish on the generally light background of the ventral surface.

Somites I, II and III are uniannulate, IV and V biannulate, and VI triannulate on the dorsal side. Somites VII and VIII are respectively triannulate and quadriannulate but VII *a3* and VIII *a1* are enlarged and quite distinctly subdivided dorsally. Then follow sixteen complete quinquiannulate somites, IX to XXIV inclusive, in which the neural annulus is typically shorter than any of the others. At the posterior end XXV is again quadriannulate, there being only one post-neural annulus (*a3*) instead of two, XXVI is biannulate with *a1* more or less distinctly separated from *a2*. The large anus cuts into the posterior margin of XXVII.

As in all of the predatory leeches of this family the mouth is of large size and may be considered to be coextensive with the opening of the oral sucker. The three jaws exhibit the usual relations, but their form is characteristic of the species among the leeches of the northern United States. They are about twice as long as high and each bears about sixty-five fine conical, slightly retrorse, uniserial teeth. A very short pharynx with several longitudinal folds reaches to about IX, within which segment it is succeeded by a still shorter œsophagus which can scarcely be distinguished from the stomach, as sacculations begin to be evident immediately. From X to XVIII inclusive each somite includes two pairs of gastric cæca of which those from XIII backward are of large size. The last pair, which originate from the stomach in the anterior part of somite XIX, are of very great extent, reaching XXIV or XXV, and bear two wide lateral branches in each of the intervening somites. The straight narrow intestine presents no noteworthy features.

Ten pairs of testes are situated, intermetamerically, as most usual in the leeches, at XIII/XIV to XXII/XXIII inclusive. The vasa deferentia are enveloped in crowded unicellular glands and follow somewhat sinuous courses. In somite XI they lose their glandular covering and appear as delicate ducts, which opposite to ganglion XI pass abruptly into the anterior end of the compact massive epididymes. From the posterior end of the latter wide somewhat folded ducti ejaculatorii lead to the terminal organ. Just before entering the outer glandular covering of the bursa or atrium the ducti become constricted and then rise as a pair of slightly enlarged sacs which open into the summit of the invaginated bursa to which they stand in the relation

of cornua. This median organ which evaginates to form the penis is in its retracted condition spherical or inverted pyriform and has thick muscular and glandular coats.

The colors during life are very showy. Above the ground varies from a light sage green to a rich olive green with obscure longitudinal stripes or short lines in the median areas. The median metameric spots are cadmium orange or light red and the marginal spots black. The ventral surface is a rich orange sometimes plain, sometimes spotted with black. The colors fade very quickly in alcohol.

Habits—This species, the native American medicinal leech, approaches closer to the European *Hirudo medicinalis,* both in structure and habits, than any other indigenous American species, and, when the use of leeches for blood-letting was more general than now, was largely employed by physicians. To a limited extent it is still gathered in the swamps below Philadelphia and sold for this purpose. It is widely distributed throughout the northern half of the United States and in Canada and is an inhabitant of standing water rather than of streams or rapidly flowing rivers. Great numbers often occur in small ponds and lakes. Altogether it is the best known of the American leeches and has been frequently written about since its discovery by Say in 1824, but its exterior has not hitherto been figured although Whitman has published drawings of the annulation of a closely allied species.

Macrobdella is more strictly aquatic than the species of *Hæmopis* and probably does not leave the water voluntarily though it will live for weeks buried in the mud left by the drying up of small ponds and pools in dry summers. It is an active predacious creature and swims actively at the surface at night or during the day if attracted by the presence of food. It is well known to the American boy who frequently comes from his plunge in the brickyard or meadow pond with several of these leeches firmly attached to his skin, an experience so frequent as to have gained for it the general name of blood-sucker.

It also attacks cattle which enter its domain to drink or cool but its natural food is the blood of fishes, frogs and turtles which it attacks and frequently kills. Small aquatic annelids in large numbers and occasionally larval insects have been found in the stomach. In the spring frogs eggs are devoured in large numbers, the eggs being sucked out after the gelatinous envelopes have been cut by the sharp saw-like teeth of the leech.

In coitus the leeches cohere by means of the secretion of the copu-

latory glands at the same time coiling somewhat about each other. Cocoons are formed and deposited in the mud by the side of the pond, and there left to hatch.

Genus Hæmopis Savigny.

Size large to very large. Dorsum plain or marked by a median stripe or by irregular non-metameric spots and blotches. Jaws small and bearing a few large double teeth, or absent; one pair of posterior gastric cæca only. Genital pores separated by five rings; no copulatory glands; penis filiform; atrium and vagina both much elongated. Food chiefly worms, insect larvae, etc., not normally blood-suckers.

Hæmopis marmoratis (Say) Moore.

(Plate IV, fig. 32)

Hirudo marmorata Say (1824)
Aulastomum lacustre Leidy (1868)
Hæmopis marmoratis Moore (1901).

Description—The size is medium, seldom exceeding six inches in length and one-third of an inch in diameter, though larger specimens are sometimes met with. Owing to the extensive development of botryoidal tissue the body is exceedingly soft and limp and consequently varies greatly in shape. Compared with the other species of *Hæmopis* described in this paper the form is rounder and less flattened than they, except in swimming, when this species also becomes flattened.

Although the anterior sucker is relatively large and the lips broad, the unsegmented margin is very narrow and there are no distinct inferior sulci as in *Macrobdella*. Of the five pairs of eyes the first three pairs are conspicuous and are arranged in a regular arc on the first three annuli; the fourth and fifth are on the sixth and ninth annuli respectively and are much more obscure, being deeply placed. All of the eyes are smaller than the corresponding ones of *Macrobdella*. In mature individuals the clitellum is very distinct and equally well developed dorsally and ventrally and often is the widest region of the body. It extends over fifteen annuli, from X *b*5 to XIII *a*2 inclusive. The posterior sucker is relatively small, circular and broadly attached; about one-third of it projects beyond the body posteriorly and its anterior margin reaches to XXV *a*2.

Somite I can seldom be distinguished from II which again is imperfectly separated from III; IV is biannulate, as is V also, but the

latter is more fully elaborated dorsally. On the typically biannulate somite VI, *a1* and *a2* are more or less separated by a furrow confined to more or less of the middle dorsal region. Somite VII is fully triannulate but is peculiar in the large size of *a3*, which, moreover, may exhibit a faint dividing furrow; VIII is quadriannulate and *a1* resembles VII *a3* in being enlarged and partly subdivided. There are fifteen (IX to XXIII) quinquiannulate somites, in which all of the annuli are approximately equal. Somite XXIV is quadriannulate and sometimes the last annulus (*a3*) is faintly subdivided, usually on the ventral surface; XXV is triannulate, but *a1*, which is normally of larger size than the remaining annuli, is subject to much variation. The following two somites, XXVI and XXVII, are variable and difficult to interpret, but the uniannulate condition is probably the most usual.

Just anterior to the jaws and separating them from the buccal is a slight circular sulcus and fold. The jaws are low and ...ed, not at all compressed on the free edge. As usual they may be retracted into little pockets so that the entire toothbearing surface is concealed. Each jaw bears a double file of large, coarse teeth arranged in from twelve to sixteen pairs. The pharynx reaches to X and has from nine to twelve or more longitudinal folds, three of which unite into a strong ridge behind each jaw. The long narrow stomach reaches to XIX, and is provided along its entire length with numerous small pockets; at its posterior end a pair of large cæca arise and reach caudad to XXII or XXIII. The intestine is also straight and bears two or three pairs of quite large, short, globular cæca which lie dorsad of the large posterior gastric cæca. The anus is very large.

The customary ten pairs of testes are present in the anterior end of somites XIV to XXIII each reaching into the preceding somite. The collecting portion of the vasa efferenta and vas deferens are essentially similar to those of *Macrobdella*. The epididymis is a rather narrow tube, much convoluted, rather open and not at all massive. The epididymis opens into the small fusiform sperm sac in the posterior part of XIII and the latter is continued as the ductus ejaculatorius. This canal reaches forward to the level of the male pore and then bends back to join the closed end of the atrium, sometimes the right, sometimes the left one, passing beneath the nerve cord. The atrium or penis sheath is very long and slender, with a sharp bend at ganglion XVII, from which point one limb reaches to the male pore, the other to the anterior end of somite XV; the ratio of the

short and long limb is about as one to two and one-third. The penis is a slender filiform organ with a slightly bulbous extremity and is frequently extruded to a length of three times the width of the leeches body. The male orifice is on the anterior part of XI *b6* or, less frequently, between this and the preceeding annulus.

The paired ovaries are situated in the posterior part of XIV dorsad of the nerve cord and in contact with the second pair of testes. There is a large albumen gland and a long narrow common oviduct which opens into the narrow anterior end of the pyriform ovisac lying in somite XVI. From the posterior end of the latter a long, slender, much convoluted vagina reaches to the female orifice at XII *b6* or XII *b5/b6*.

Hæmopis marmoratis includes many color varieties. The ground is usually some shade of green, olive green or greenish brown, sometimes nearly plain, sometimes remotely spotted, but usually thickly and confluently blotched with irregular or intermixed spots of lighter grays and darker browns or black. The lighter kinds tend to predominate on the ventral side, from which the darker pigments may be altogether absent. The darker markings are sometimes so close on the dorsal surface as to produce an almost black color.

Habits—The horse leech, as this species is called, is found in practically all parts of North America, where it has a known wider range than any of its near allies. It is semi-aquatic, living in the mud by the sides of ponds, pools, and lakes rather than actually in the water, although it of course moves freely about in the water and is often found in the mud at the bottom. Along tidal rivers the species is most abundant beneath stones on the flats exposed at low water where it lives with several species of true earthworms. At times it wanders some distance away from the waters edge, burrowing in the soil in search of the earthworms on which it feeds; but it is not terrestrial in the sense in which *H. lateralis* is, never leaving, so far as has been observed, the near vicinity of water. Besides earthworms, various kinds of aquatic insects and their larvae, aquatic oligochaetes, gastropods and pelecypods are pursued and eaten and large quantities of mud containing organic matter are swallowed. The species is also, like many other leeches, a scavenger and great numbers will collect on the body of a recently killed animal thrown into their haunts. Blood is also taken when the opportunity is afforded of attaching itself to drinking cattle or the legs of boys wading in its haunts. It would be interesting to know if it ever enters the pharynx of cattle,

as is well known to be the habit of the *Limnatis* so common in some of the countries bordering on the Mediterranean.

Hæmopis lateralis (Say) Moore.

(Plate III, fig. 23)

Hirudo lateralis Say (1824).
? *Macrobdella valdiviana* et *gigas* Philippi (1872)
Semicolex terrestris Forbes (1890)
Hæmopis lateralis Moore (1901)

Description—Although there are some minor differences I am unable to separate the aquatic leech originally described by Say from specimens procured in Minnesota from the interesting terrestrial form which Forbes has described and which was found by him in considerable numbers in garden soil in Illinois. So far only the aquatic variety has been found in Minnesota and was represented in the Survey collections by two living examples which unfortunately escaped from me and were lost.

Compared with the terrestrial variety, of which even Prof. Forbes' contracted alcoholic specimens reach a length of eight inches, a large number of the aquatic form, chiefly from Ohio and Maryland, average much smaller, about five inches long and one-half inch wide being the usual size. This species is much more slender than *H. marmoratis* and the greatest width lies farther caudad. The body is rather more muscular and as a consequence firmer, but during life exhibits the same variety of shapes and postures.

The mouth is somewhat smaller and the oral sucker narrower than is *H. marmoratis*, while a further slight distinction is found in the better developed longitudinal grooves beneath the lips of this species. The eyes have the same number and position as in the species last described.

In the few cases in which a clitellum has been observed it differs in no respect from *H. marmoratis*. Although not differing in any way from the typical arrangement in the family, the seventeen pairs of nephridropores on the posterior margin of *b*2 of somites VIII to XXIV inclusive are unusually distinct and lie just behind a sort of slight spout-like projection. The posterior sucker is noticeably small.

Throughout the entire length of the body the annulation is very distinct, and at the margins most of the annuli are rather sharply angulated. In most respects the somites are constituted just as in

H. marmoratis but the following features are diagnostic: Somite VII is fully quadriannulate and VIII quinquiannulate, owing to the complete subdivision of VII *a3* and VIII *a1* each into two annuli; as a consequence this species has two more annuli in the anterior region; VI *a3* and VII *a1* are always relatively wider and may exhibit an incipient furrow; on the complete somites the annuli are not equal but bear the following relation:—$a2<b1=b2<b5=b6$, except at the posterior end of the series; finally XXVI and XXVII are typically biannulate.

Including the rudimentary denticles at the posterior end each jaw bears from twenty to twenty-five pairs of teeth, of smaller size and more irregular form than in *H. marmoratis*. In other respects the digestive organs are essentially similar in the two species.

The sperm sacs and epididymes do not reach beyond ganglion XI anteriorly, or ganglion XII posteriorly; the latter are massive and compact and partly envelope the sperm sacs to which they are closely moulded. The posterior bend of the atrium is at ganglion XIV and the relative length of the two limbs is as one to one and seven-tenths in three examples measured. Although the genital pores are in the homologous annulus they lie two annuli farther from the mouth than in *H. marmoratis*. The ovaries are always within somite XII, and the vagina never extends posterior to ganglion XIV.

Forbes thus describes the colors of living examples of the terrestrial variety—"sooty drab, varying to plumbeous black, somewhat lighter beneath, uniform in tint and quite without spots or mottlings of any sort. A darker median longitudinal stripe, very conspicuous and well defined, is almost invariably present; a paler marginal stripe often approaching buff, little less constantly so; and a ventral submarginal stripe of the same color as the median dorsal one likewise quite frequent." The ground color of the aquatic variety is similar, but while the dorsal black stripe is less constant it may be very conspicuous; more frequently it is faint and obscure, broken into small spots or totally wanting. A few small dark spots are sometimes scattered over the dorsum. Sensillæ are much more distinct in the aquatic than in the terrestrial variety; indeed Forbes failed to find them in the living specimens of the latter.

Habits—In habitat, food, movements, resting attitudes etc. the aquatic variety is essentially like *H. marmoratis*. It is capable of a greater degree of extension and appears to be a more active swimmer than that species. Two examples sent to me by Prof. Nachrtieb and

the only ones included in his collections were placed in an aquarium with *H. grandis*. One night the cover was accidentally left displaced and on my arrival the following morning both were gone, but none of the other species were missing. A shining track of dried mucous on the polished floor showed the course of their wanderings. One quickly disappeared beneath a wall case. The other was tracked for a measured distance of more than fifteen yards, when it too disappeared beneath the wash-board. Neither was recovered, but the circumstance is mentioned as showing the tendency of this species to wander and its ability to live in a perfectly dry situation, and as further confirmation of my opinion of the identity of this with the land leech of Illinois. Under the same circumstances *Hæmopis marmoratis* or *Erpobdella punctata* would have quickly died before having crawled nearly so great a distance, as I know from experience. Concerning the terrestrial form Prof. Forbes writes of having obtained fifty-six specimens, all from the earth in central Illinois and some of them half a mile or more from the nearest water, while none occurred in the course of a large amount of aquatic work done in the same regions during the same period. Its only known food is earthworms which it swallows entire. From the fact that his specimens were all obtained from March to June, Prof. Forbes suggests that it is probable that this species penetrates the soil to considerable depths during the midsummer draughts. So far as I know the terrestrial form has been taken by no one else in this country, but a very large terrestrial leech found by Philippi in Chile is indistinguishable in the description and excellent figure from Forbes species.

Hæmopis plumbeus sp. nov.

(Plate IV. figs. 29, 30, 31)

? *Hirudo lateralis* Say (1824) in part.

Description—Though resembling *H. lateralis* quite closely in color this hitherto unnamed form stands much nearer to *H. grandis*, to be next described, in respect to both internal and external structure. The features in which it differs from the latter are rather slight but have proved quite constant in all of the specimens examined. Probably this species does not equal *H. grandis* in size, the available specimens varying between two and six inches in length. The form is heavy like that species, and the oral sucker larger and lips much broader. A rather wider unsegmented rim borders the sucker. Except that they are rather larger the eyes are like those of *H. grandis* in structure and arrange-

ment. The sensillæ, nephridiopores and anus present no distinctive features. None of the specimens examined has the clitellum developed.

The annulation is essentially like that of *H. grandis* but a few differences occur, which may disappear when a larger series of specimens comes to be compared. The furrows are well marked but present little of that zigzag character and secondary wrinkling which is so conspicuous in the larger species. This difference is very marked in specimens of the two species of equal size and preserved together, so that it may prove not to be accidental. The furrow V *a1/a2* is quite incipient and the annuli VII *a3* and VIII *a1* are relatively much smaller and very much less distinctly subdivided than in *H. grandis.*

The mouth is very large and the ventral surface of the lip shows no trace of longitudinal sulci. Jaws are absent and the capacious pharynx bears twelve very low longitudinal folds. The remainder of the alimentary canal appears to differ in no way from that of *H. grandis.*

The external genital orifices are constantly in the middle of annuli XI *b6* and XII *b6* respectively, while in *H. grandis* the male pore is almost invariably at XI *b5/b6* and the female in the anterior part of XII *b6*. The penis is filiform and may protrude to a length of two and one-half times the width of the body at the male orifice. It is in the structure of the internal reproductive organs that the most evident differences between this species and *H. grandis* are found. In fact the resemblance is much closer to *H. marmoratis* in respect to these organs. The atrium extends caudad far beyond the vagina to the neighborhood of ganglion XVI where the usual sharp bend occurs. The short limb is about one-half as long as the long one. Relatively small sperm sacs, which are not more than one-fourth or one-fifth of the length of the atrium, lie far forward in the region of the male orifice. The coils of the epididymes lie chiefly by the side of the sperm sacs and not heaped up at their caudal end as in *H. grandis.* Unlike any other species of the genus described in this paper the vagina is very much shorter than the atrium, reaching only to the caudal end of the somite XIV. The common oviduct lies on the dorsal side of the vagina; the albumen gland is large and nearly spherical and the ovaries are just in advance of the female pore.

The color is a remarkably uniform leaden or slaty gray, usually purer and sometimes darker below, and often showing a slight olive or yellowish tinge above. Along the entire lateral margins from the

caudal sucker to the lips is a broad, dull but conspicuous rufous or orange band which broadens and encroaches on the dorsal surface as it approaches close to the head, but contracts again on the lip to a narrow marginal line. The ventral margin of this band is, owing to the purer ground color below, more sharply defined. Small irregular spots of black are scattered more or less remotely over the dorsum, being usually most numerous toward the margins and ends of the body, especially in the specimen figured. Sometimes they are almost absent and are never numerous. Except for a few along the lateral rufous band the ventral surface is free from spots. The caudal sucker is of the ground color both above and below, with a narrow rufous border.

Nothing distinctive concerning the habits of this leech is known to me and I have seen no examples except those in this collection from northern Minnesota.

It seems very probable that the presence of spots which Say attributes to his *H. lateralis* may have applied to this species rather than the one which is represented by Say's supposed type. The spots are much more conspicuous and constant in this than in that species and as the coloring is otherwise almost identical and both species occur in the precise region from which his types came Say might easily have confused them.

Hæmopis grandis (Verrill).

(Plate IV, figs. 26, 27, 28; Plate V, fig. 37)

Semiscolex grandis Verrill (1874).

Description—As Prof. Verrill indicated in his original description this is a monster among American leeches, exceeding the North American representatives of the terrestrial variety of *H. lateralis* and at least equaling the larger representatives of that species which Philippi has described from Chile under the names of *Macrobdella valdiviana* and *M. gigas*. Living examples not infrequently exceed a foot in length and specimens of fifteen or even eighteen inches have been reported from the lakes of Minnesota. However, this is an unusual size and smaller individuals having a length of from five to eight inches are much more common.

The body is very robust and heavy posteriorly, but rather slender anterior to the clitellum. While seldom much depressed the body does not assume the quite rounded form frequent in *H. marmoratis*, which some varieties of this leech closely resemble in general aspect. In

life the body is soft and limp and possesses a great facility for contraction and elongation and other changes of form.

While large, the mouth is more contracted than in *H. plumbeus* and the lip narrower and more prolonged. The five pairs of eyes have the arrangement usual in the family; they are all of relatively small size and the fourth and fifth pairs quite inconspicuous.

The clitellum is a thick and prominent glandular girdle extending over fifteen annuli from X *b5* to XIII *b2*, often rather within the latter but apparently never as far as its middle. The female orifice is similar but drawn out laterally to a slit-like form and usually well within annulus XII *b5*, sometimes as far back as its middle or so far forward as to lie in the furrow XII *a2*/*b5*.

Seventeen pairs of nephridiopores can be readily distinguished on the posterior margins of the first annulus (*a1*) of VIII and the second annulus (*b2*) of somites IX to XXIV inclusive. They, together with the metameric sensillæ, have the positions usual in the genus and the marginal sensillæ show the same tendency to become subdivided. There are no cutaneous papillæ, the skin being smooth. However, the short shallow wrinkles seen in many large leeches are remarkably conspicuous in preserved specimens of this species and give to the interannular furrows a peculiar zigzag course which is especially pronounced toward the ends of the body. The usual non-metameric sense organs are present in abundance and are especially numerous on the lips. The annulation differs in no essential feature from that already described for *Macmopis marmoratis*.

While retaining all of the characteristics of the genus the reproductive organs differ considerably in the proportions of the several regions of the complicated ducts from all of the other species found in Minnesota. The epididymis is remarkably massive and lies chiefly caudad of the corresponding sperm sac which is consequently not so largely enclosed in its coils as in *H. lateralis*. The sperm sac is remarkably large, being much wider than and about half as long as the atrium when fully distended, as in the specimen figured. Its anterior end is just behind ganglion XII and tapers into the ductus ejaculatorius which is noteworthy for its shortness. In almost every instance the atrium is doubled on itself at about the middle, so that the two limbs are approximately equal and the blind glandular end is usually a little anterior to the male pore. Either the right or left ductus ejaculatorius may pass beneath the nerve cord.

The ovaries are situated in the anterior part of XIII immediately

behind the female pore, and both may lie dorsad of the nerve cord or one pass beneath it. There is a large pyriform albumen gland, a short common oviduct and a relatively short, thick vagina.

A median and one or two pairs of lateral longitudinal furrows, together with some less constant and minor ones, mark the ventral surface of the lip. The transverse sulcus dividing the buccal chamber from the pharynx is deeper than usual, which is perhaps correlated with the entire absence of dentigerous jaws in this as in the last described species. Although somewhat variable and irregular there are typically about twelve prominent longitudinal pharyngeal folds. Nine of these are in three groups of three each coalescing anteriorly at what would be the position of the jaws in other species. Three, unusually simple and frequently incomplete folds, alternate with these. The stomach scarcely shows any indication of lateral pouches and the posterior pair of cæca are remarkably short, scarcely one-half the length of the intestine.

On the dorsal surface the ground color varies from tawny olive through olive and olive green to oil green, the green colors being nearly pure in some examples, especially in those which are least spotted. In others they are impure from the suffusion of brown or dusky pigments in the deeper tissues, in extreme cases imparting to the entire dorsum a brownish hue. The lighter greens appear most frequently toward the anterior end and on the caudal sucker, but in many examples these regions become dusky. Frequently a marginal rufous or orange stripe is present, especially toward the posterior end, but it is seldom or never so clearly defined as in *H. plumbeus*. The ventral surface is gray, yellowish or light brown but always paler than the dorsum.

There is a great range in the degree of maculation which, as compared with *H. marmoratis*, is characterized by a greater boldness and distinctness in this species. Perhaps the most typical condition is that in which the dorsum of each complete somite is marked by eight or ten irregular but somewhat quadrate black spots, most of which are confined to the limits of one annulus, but a few, especially toward the margins, are larger and more irregular. In other cases the spots are much more numerous and confluent so that the real ground color appears as lighter areas on the dark field. Still others are as nearly free from spots as some examples of *H. plumbeus*. The ventral surface bears fewer spots than the dorsal and not infrequently is quite immaculate.

Habits—This great leech is found on the shores of the Great Lakes and abounds in the numerous lakes and ponds of Wisconsin, Minnesota and Michigan. Eastwardly it extends its range through New York into New England but is rare in the Middle States and I have had but little opportunity to study its habits under natural conditions.

It appears to live chiefly about the borders of the bodies of water which it affects, concealing itself beneath stones. According to Barrows it secretes an unusual abundance of mucous and I suspect from this fact and the large size of the nephridial bladders that it may upon occasion leave the water. Stomach examinations show that its food consists of earthworms and allied aquatic worms, smaller leeches, particularly the nephelids, snails, insect larvæ and organic mud. In captivity several individuals fed voraciously on earthworms but could not be induced to attack fishes, frogs or turtles even when the skin was abraded so that the blood flowed, from which behavior it would appear that the accounts of this species habitually attacking fish require to be verified.

Family Herpobdellidæ.

Leeches of mostly moderate size and slender elongated form, usually terete anteriorly, often much depressed posteriorly. Clitellum as in Hirudinidæ. Oral sucker small, forming lips; caudal sucker also small, discoid. Complete somites fundamentally of five rings, but one or more often subdivided, forming six to eleven rings. Eyes usually four pairs, two pairs on somite II often coalesced, two pairs of smaller size on IV; but sometimes eyeless. Cutaneous sense organs and papillæ numerous, not obviously metameric. Mouth and pharynx as in *Hirudinidæ*, but the latter with three longitudinal muscular ridges and no jaws. Stomach and intestine straight, simple and without diverticula. Genital orifices variable in position, the male usually on XII, the female on XIII. Testes sacs small and very numerous, extending through about segments XVIII to XXIII. Sperm ducts very long and much convoluted, paired until they empty by means of the short prostate cornua into the small median atrium. No protrusible penis. Ovisacs long and slender as in *Glossiphonidæ* but each doubled on itself, united only at the external orifice. Copulation takes place and spermatophores are implanted on the integument. Eggs enclosed in flat, pouch-like chitinoid cocoons fastened by one side to stones, sticks, plants, etc. Fresh water predaceous leeches, feeding on insect larvæ, worms, etc., occasionally suck the blood of vertebrates.

Genus Erpobdella Blainville.

Size moderate; posterior region not greatly depressed. Sperm duct forming a long loop (reaching to ganglion XI) anterior to atrium, which is provided with a pair of simply curved horns. None of the five annuli of complete segments distinctly enlarged and subdivided.

Erpobdella punctata (Leidy) Moore.

(Plate IV, fig. 39)

Nephelis punctata Leidy (1870)
Nephelis lateralis Bristol (1898) in part.
Erpobdella punctata Moore (1901)

Description—The form is elongated with the sides nearly parallel, tapering anteriorly to the clitellum but very little at the posterior end. Anteriorly it becomes almost circular in section and posteriorly, although margins are sharp and prominent, is little depressed and widened. The size is large for the family, reaching a length of about five inches. The body is very firm, hard and muscular.

The oral sucker is very small, being little more than a short lip overhanging the nearly terminal mouth. Normally there are three pairs of eyes, the first decidedly the largest and situated close together on somite II and directed forward; the others more widely separated on the sides of IV and looking somewhat backward. The clitellum is frequently seen in full development, in which condition it is a wide, thick complete girdle covering the fifteen annuli from X *b5* to XIII *a2* inclusive. The male pore is a rather conspicuous opening at XII *b2/a2*, the female a much smaller one at XII *b5/b6* or two annuli farther caudad.

Somites I, II and III are uniannulate; IV and V are biannulate, VI is triannulate, VII quadriannulate; and VIII to XXIV inclusive, or seventeen somites, are quinquiannulate. At the posterior end somite XXV is quadriannulate, though the last annulus (*a3*) may be more or less distinctly subdivided on the dorsum; XXVI is either biannulate or triannulate and XXVII is usually uniannulate.

In the complete somites the annuli are of approximately equal length and *b6* is not obviously enlarged or more completely subdivided than the others. Numerous small cutaneous papillæ bearing sense organs appear arranged in an irregular transverse row on each annulus. They are largest dorsally and on the neural annulus. The annuli of the simpler somites frequently exhibit two such rows, indicating their composite character.

The testes are numerous, about fifty to sixty on each side of somites XVIII to XXIV, mostly with separate vasa efferentia. The enlarged and much convoluted epididymis or sperm sac reaches from XVIII to XIV. There is a long pre-atrial loop to the ejaculatory duct reaching to ganglion XI. The atrium consists of a small eversible bursa and a pair of elongated semi-erect, curved prostate cornua, the bases of which are enveloped by a thick layer of prostate glands. The ovaries are elongated sacs each doubled on itself and reaching for a variable distance through the ventral sinus.

In this species the color varies extremely. Young individuals usually contain little or no pigment, permitting the red color of the blood to appear through the translucent tissues. The adult pigmentation is assumed gradually with increase in age and size. When full grown the ground color may be plumbeous, slate color, brownish gray, olive brown, fuscous, light brown or chocolate, always somewhat lighter ventrally and in the furrows and enlivened on the margins by the red tint of the lateral blood vessel. Sometimes a beautiful golden green hue overspreads the entire dorsum. The browns are most usual and may be plain or more usually more or less marked with irregular black spots with light centers, arranged in two or four longitudinal lines leaving the middle of the back and the margins clear.

Habits—Within the area of its distribution, which is extensive, this leech occurs under a great variety of conditions. Almost every spring, brook and river, ditch, pond and lake, no matter how pure and cold or how warm and foul, is its home. And in most situations it is by far the most common species of leech present, exceeding in numbers even the omnipresent *Glossiphonia stagnalis*. The size varies greatly with the extent of the body of water and the richness of the food supply. Small clear brooks and ditches almost invariably yield only small individuals, while by far the largest individuals which I have seen come from large rivers and ponds and the Great Lakes. Bristol has pointed out that in any particular pond they congregate on the shore which receives the richest food supply and my own experience substantiates this.

Like many other species of leeches this one conceals itself during the day beneath stones, logs, leaves or whatever happens to be convenient for the purpose, but leaves its shelter at night and searches actively for food. In aquaria the rhythmic respiratory movement, which takes place while either both or only the posterior sucker is attached, may be frequently observed. It is so muscular and the body so

hard, wiry and slippery that it is really quite difficult to hold a living one between the fingers. When picked up it struggles and writhes violently and when disturbed creeps rapidly. It is also the most expert and active swimmer of any of our common leeches. When swimming it turns edgewise and undulates the body in eel-like fashion, sometimes elevating the head above the surface.

Although somewhat of a scavenger, it subsists chiefly on aquatic insects and their larvæ, and aquatic oligochaetes, but will attack fishes and frogs or draw blood from the legs of wading boys. Not infrequently cannibalistic tendencies appear, large individuals devouring the smaller ones of their own species. It is very active in seeking food and will pursue its prey with considerable tenacity.

Breeding continues over a long period—most of the spring and summer. Spermatophores are formed and attached to any part of the body except the anterior end which seems to be avoided. In copulation the two leeches wind about each other and adhere by means of their suckers and the exchange of spermatophores may be mutual. The small, flat, amber-colored egg cases are familiar objects to students of fresh water life and are often found in great numbers attached to the underside of stones etc. in the water.

Genus Nephelopsis Verrill.

Size large; much depressed posteriorly. Sperm duct forms a loop as in *Erpobdella;* atrial cornua prominent and with a complete spiral turn. All annuli of complete somites more or less distinctly subdivided.

Nephelopsis obscura Verrill.

(Plate V. figs. 35, 36; Plate VI. fig. 40)

Nephelopsis obscura Verrill (1872).

Description—Like the species last described this is a rather large leech, attaining a length nearly equal to *Erpobdella punctata* and considerably exceeding it in the breadth of the posterior region of the body. Compared with other species of the family belonging to the Minnesota fauna the body is more depressed and in its posterior part very much broader than they. The margins are sharp and prominent. The region anterior to the clitellum is relatively slender and subdepressed with rounded margins. Texture hard and firm.

Nothing characteristic appears in connection with the mouth and lip which is rather broad. There are four pairs of eyes of about equal

size; the anterior two pairs are situated nearly side by side in somite II, or the more lateral pair in a slightly more caudal position on the furrow II/III. Both are directed forward and slightly lateral. The remaining two pairs are situated farther back but similarly close together on the sides of the oral annulus IV. Usually they are on the posterior part of the larger annulus but their pigment cups may lie beneath the furrow *a2/a3*. Both are directed caudad and laterad.

Fifteen annuli, X *b5* to XIII *a2* inclusive, are occupied by the prominent clitellum. The external genital orifices are separated by two annuli situated as in *E. punctata* at the furrows XII *b2/a2* and XII *b5/b6* respectively. In individuals which are in active sexual condition, the male orifice is a conspicuous opening more or less elevated on pouted lips marked by radiating furrows. Occasionally the genital bursa is everted as an elliptical disc with a central platform-like elevation perforated by a single median pore or a pair of pores, dependent on the more or less complete protrusion of the organ. In small individuals and those not sexually active the male pore is minute, as the female invariably is.

The anus is a rather large transverse slit with wrinkled margins situated in XXVI and succeeded by several rather ill defined annuli belonging to XXVII. The caudal sucker is a thin, flat, expansive and largely exposed disc. Its dorsal surface is marked as in *E. punctata* by six or eight radiating ridges.

In one respect the reproductive organs are very characteristic. While in general resembling *E. punctata* the atrial cornua are larger and coiled in a complete spiral turn, which is invariably present in a large number of individuals of all sizes and conditions which have been dissected. The pre-atrial loops reach to ganglion XI.

The ground color is generally gray, clay color or brownish, the latter occurring most frequently on plain unspotted examples. By far the greater number of specimens are thickly spotted over the entire dorsal surface with black. These blotches are not coarse and heavy as in *Hæmopis marmoratis* to which the species exhibits some resemblance in color, but are finely branched and ramifying, with frequently anastomosed terminal branches, thus affecting a more or less evident and continuous network. Sometimes the black spots are quite few and remote, again they become so predominant that the ground color is very largely obliterated and the dorsum presents a generally slate black color spotted more or less remotely with the lighter ground.

In any case, whether the spots be few or many, there is no evident

metamerism in its pattern and no tendency toward the formation of longitudinal stripes, the pigment being quite as continuous across the middle line as elsewhere. Except in the very heavily blotched specimens, in which a few spots occur, especially toward the margins, the ventral surface is immaculate.

Habits—The exact geographical range of this species is not yet known but it is especially characteristic of the Mississippi Valley and the lake region drained by the headwaters and tributaries of that river. It is exceedingly abundant in Wyoming, Wisconsin and Minnesota, but is known to extend as far south as Alabama. The stomachs contain large numbers of insect larvæ, which appear to furnish the chief sustenance, but also various species of Oligochæta, aquatic snails etc. No opportunity has been afforded me to study the habits of this species but there is no reason to believe that they differ materially from those of *E. punctata.* Verrill has described the egg cases as "broad oval or elliptical, terminating in a point or mucro at each end, flat below, smooth and slightly convex above, with a thin margin. They were 5.5 mm. to 8 mm. long by 3.5 mm. to 4 mm. broad."

Genus Dina R. Blanchard.

Size rather small; not greatly depressed posteriorly. Sperm duct not forming a long anterior loop reaching to ganglion XI; atrial cornua small. Last annulus of each complete somite obviously enlarged and subdivided.

Dina parva. sp. nov.

(Plate V. figs. 33, 34; Plate VI, figs. 41, 43.)

Description—A number of small and imperfectly preserved leeches from Gull Lake show characters which readily distinguish them from any species of *Dina* previously described. The species exhibits certain resemblances to *Nephelis fervida* Verrill, and may indeed prove to be that species instead of the one which was so identified in my paper on the leeches of Illinois. There is nothing in the original description of *N. fervida* except the size which will permit one to discriminate between the two.

None of the specimens at hand exeed an inch in length in the partly contracted state and if alive and extended would not be more than one and one-half inches. Posteriorly the body is relatively wide and flat but anteriorly becomes nearly circular behind the mouth. The mouth and lips have the customary form. Unlike most of our Amer-

ican species there are four pairs of conspicuous black eyes, though variations in which one or both of the anterior lateral ones are absent occur in about ten per cent of those studied. The anterior eyes are larger than the posterior, those of the two pairs almost in contact and their pigment cups situated well within somite III. The posterior eyes are smaller, looking outwards and backwards from the lateral faces of the posterior part of IV.

The genital orifices are separated by a greater distance (normally three and one-half annuli) than is the case in any other known American species. The male pore is a conspicuous transverse opening elevated on a broad low papilla in the middle of XII *a2*, and the female a very minute opening between the annuli XIII *b1/b2*. Considerable variation, in the posterior direction, occurs in the position of the male pore. In about five per cent of the cases it has been found at the posterior part of its annulus, in the succeeding furrow (XII *a2/b5*) or even within the annulus XII *b5*. No variations in the position of the female opening have been observed. Nothing of importance can be noted with regard to the nephridiopores, anus or posterior sucker.

Concerning the annulation reference may be made to figures 33 and 34 on Plate V and figure 43 on Plate VI. Both somites II and III appear to be biannulate and at least the outermost pair of eyes of the anterior group are well within the latter. Somite V is also biannulate, VI triannulate and VII quadriannulate. Beginning with VII annulus *b6* shows its larger size and by IX is fully subdivided. In most of the complete quinquiannulate somites, of which there are seventeen (VIII to XXIV), this large size of *b6* and its subdivision is very clearly manifested. Toward the caudal end XXV is quadriannulate, XXVI triannulate and XXVII two or three small rings behind the anus.

Owing to maceration the characters of the testes cannot be satisfactorily determined but apparently they are even smaller and more numerous than usual in the family. The specialized anterior portion of the vasa deferentia extends through a smaller number of somites than usual, the sperm sac reaching from ganglion XVI only to XIV or thereabout, within which region it is of large size and much folded. The pre-atrial loop of the ejaculatory canal reaches to ganglion XI and just before entering the atrial cornua the duct is folded laterally several times. The atrium itself has simply curved horns. Its median part crowds the twelfth ganglion somewhat caudad out of its usual position.

Whatever pigment may have been present has faded out completely in the preserved material. Nothing is known concerning the habits of this species.

Dina fervida (Verrill) Moore.

(Plate VI, fig. 42)

Nephelis fervida Verrill (1874).
Dina fervida Moore (1901)

Description—The length of this species is not known to exceed three inches and more often reaches but two. The body is depressed posteriorly but rounded anteriorly. The mouth is of relatively large size and the lips broadly rounded. More characteristic is the large size of the caudal sucker which has a greater expanse than in most small nephelids, the anterior margin being more widely free and reaching as far forward as XXV *a2*. If one may judge from the preparations the body is not of particularly firm consistency; certain it is that the muscular system is less well developed than in the hard species. The usual thick prominent clitellum reaches from X *b5* to XIII *a2* covering fifteen annuli. The external genital orifices are separated by two annuli, the male being situated at XII *b2/a2*, the female at XII *b5/b6*. Three pairs of eyes are more usual than four. They resemble those of *E. punctata* except that the pigment cups of the first pair lie chiefly within somite III.

There is little of diagnostic value in the annulation. Some features of the sense organs are peculiar but have no considerable value in defining species. The last annulus (*b6*) of each somite is much longer and more fully and constantly subdivided than any of the others, as in other members of the genus.

The species is very readily distinguished from *D. parva* by the character of the reproductive organs. The testes occupy the lateral portions of somites XVIII to XXIV, and average in the one individual in which they were all counted thirty-two on each side of a somite. The several regions of the sperm ducts exhibit no peculiarities until the atrium is reached. Here the entire absence of a preatrial loop is noted, the ejaculatory canals stopping abruptly at the apices of the atrial cornua into which they enter. When the copulatory organ is fully retracted the ducti form no loop whatever anterior to the atrium but when, in protrusion, the cornua are drawn somewhat caudad, they sweep somewhat anterior to it in a broad curve. The atrium itself is characterized by the relatively large size and quite un-

divided form of the median portion and the widely divergent short cornua. In these respects and also in the fact that the prostate gland covers the dorsum of the median chamber as well as the bases of the cornua, this species resembles *D. microstoma* most closely.

Two distinct color varieties occur, both of which have a dusky red color, during life, due to the blood. In one, pigment appears to be nearly or quite absent, a condition which characterizes all of the young and a few of the adults. The other and more usual variety has the dorsum marked with more or less numerous minute black flecks which vary greatly in number and somewhat in arrangement. Many specimens are so little pigmented as to appear quite light colored; such are usually marked with a pair of dark longitudinal stripes one on each side of a clear median area, in others these stripes become very broad and in still others the whole dorsum except the margins is deeply pigmented.

Habits—So far as now known *Dina fervida* belongs to the fauna of the Great Lakes and the immediately surrounding region, where it is quite common. The food contents of the stomach consist largely of tubificid worms and some insect larvæ. Verrill has described the egg capsules which are attached to the leaves of Nuphar as "broad-oval or elliptical, above smooth and convex, translucent yellowish brown, with a thin, flat lighter border, each end prolonged into a short tubular neck, with a terminal orifice. Lower surface flat." They measure from 9.5 to 11.5 mm. long which seems remarkably large for a species of the size of this.

PLATES I-VI
AND
EXPLANATIONS

PART III

GENERAL EXPLANATIONS

Roman numerals I to XXXIV refer to somites.
The letters *a, b, c* and *d* with Arabic numerals refer to the annuli.
For a full explanation see pages 17 to 19.

The cutaneous papillæ are designated as follows:

dlp.....dorso-lateral
dmp.....dorso-marginal
mdp.....dorso-median
mp.....median
smp.....supra-marginal

The metameric sensillæ are designated as follows:—

dl.....dorso-lateral
dm.....dorso-marginal
md.....dorso-median
sbm.....sub-marginal
sm.....supra-marginal
vl.....ventro-marginal
vm.....ventro-median
♂.....Male, or the external opening of the male genital organs or its position.
♀.....Female, or the external opening of the female genital organs or its position.

Special legends will be found in the explanations of the respective plates.

PLATE I.

Glossiphonia stagnalis. x 20.

Fig. 1. Dorsal view of the first twelve somites. The positions of the genital pores on the ventral side are also indicated.
ng.....nuchal gland.

Glossiphonia nepheloidea. x 56.

Fig. 2. Dorsal view of the first ten somites.

Glossiphonia fusca. x 30.

Fig. 3. Dorsal view of the first ten somites of a young example, showing the metameric sensillæ and papillæ.

Glossiphonia complanata. x 18.

Fig. 4. Dorsal view of the first ten somites. The paramedian stripes are shown but the papillæ and sensillæ are omitted.

Placobdella montifera. x 13.

Fig. 5. Outlines of part of the reproductive organs, dissected. The folds of the epididymis and ejaculatory canal are drawn aside to show their length. A portion of the ventral nerve cord is included to show the segmental position of the parts.
at.....Atrium
de.....Ejaculatory canal of the spermduct
ep.....Epididymis
ov.....Ovary or ovarian sac
t1.....First testis
vd.....Vas deferens

Placobdella rugosa. x 5.

Fig. 6. Dorsal view of the first ten somites. All of the papillæ and most of the metameric sensillæ are shown but not the color pattern.

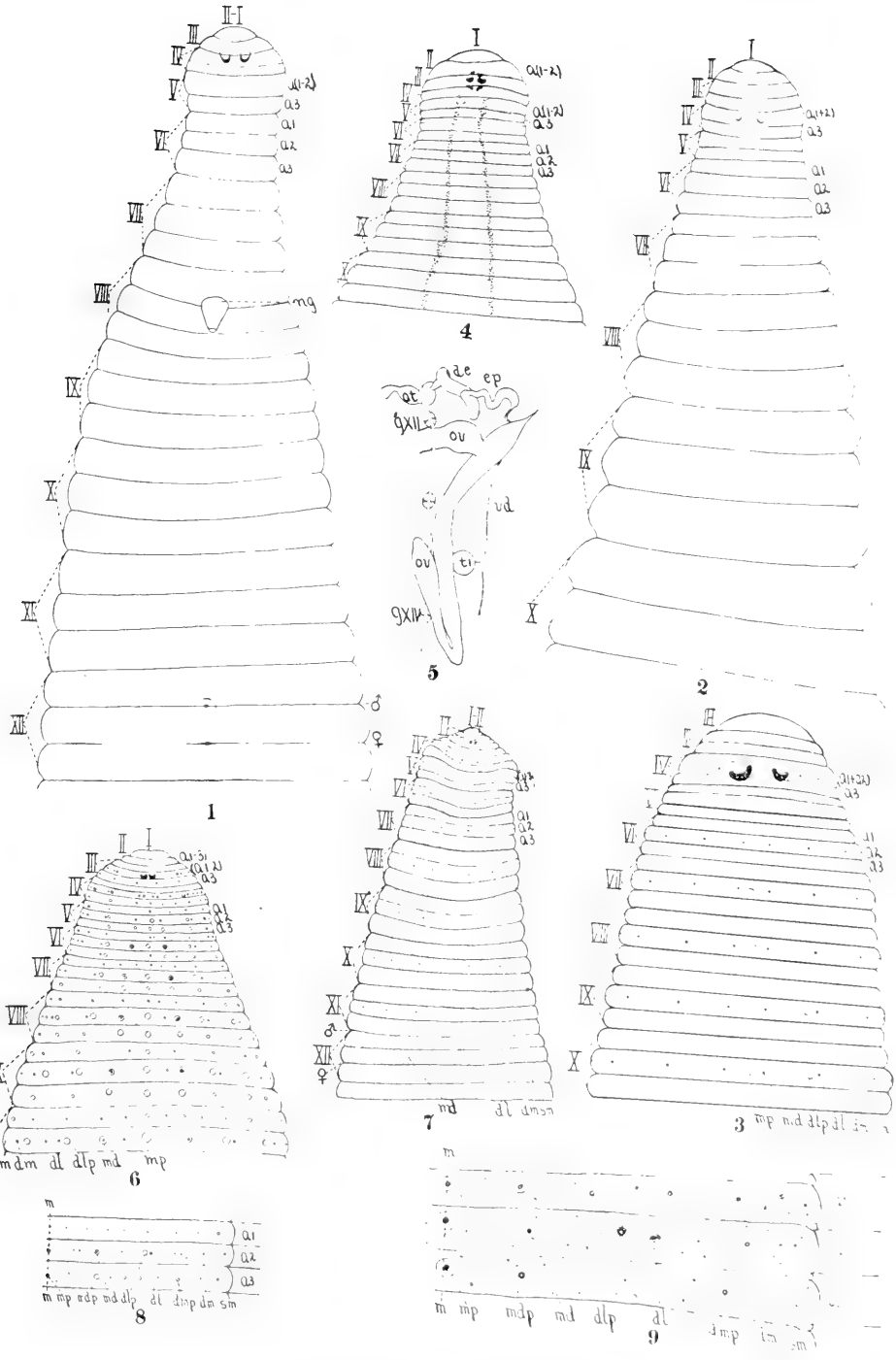
Placobdella parasitica. x 5.

Fig. 7. Dorsal view of the first twelve somites. The dark colored background is shown by stippling, the yellow vitta and spot being plain. The papillæ are omitted but the positions of the genital orifices on the ventral side are indicated.

Fig. 8. Papillæ and sensillæ of the right half of the dorsal surface of somite XIX of a medium-sized example. The lines to the right indicate the relative positions of the furrows on the ventral side.

Placobdella rugosa. x 5.

Fig. 9. Papillæ and sensillæ of the dorsal surface of the right half of somite XIX of a large example. The lines to the right indicate the relative positions of the furrows on the ventral side.



Glossiphonia. Placobdella.

PLATE II.

Placobdella montifera. x 4.5.

Fig. 10. The principal features of the external morphology of the dorsum of somites I-XII. Very slightly diagrammatic.

Placobdella hollensis. x 8.

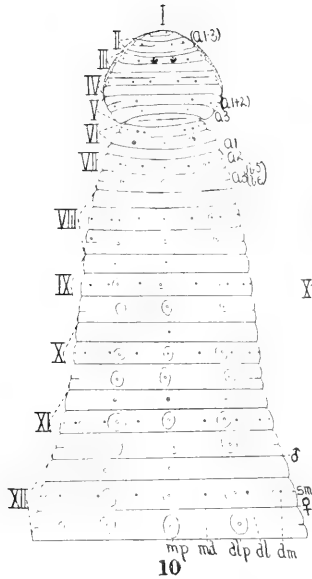
Fig. 11. Dorsal view of the first ten somites.

Hemiclepsis occidentalis. x 56.

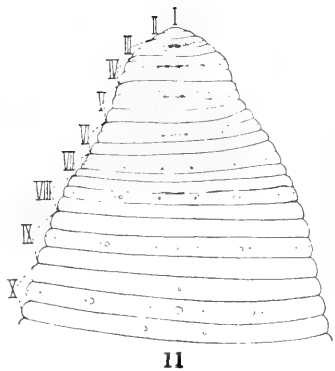
Fig. 12. Dorsal view of the first ten somites of a young example still remaining with the parent, showing the annuli and the eyes.

Placobdella pediculata. x 3.5.

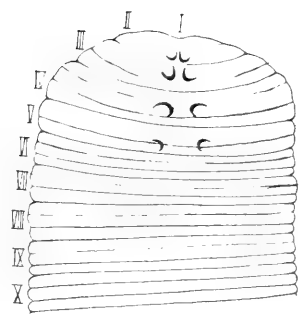
Fig. 13. Ventral view of the anterior thirteen somites.
Fig. 14. Dorsal view of the anterior thirteen somites.
Fig. 15. The head end as seen from in front.
Figs. 16, 17 and 18. Dorsal, ventral and lateral view respectively of the posterior end, showing the annulation and the peculiarities of the caudal sucker and its peduncle.



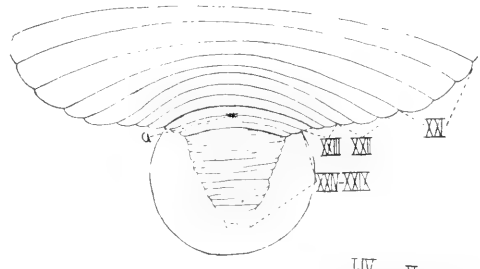
10



11

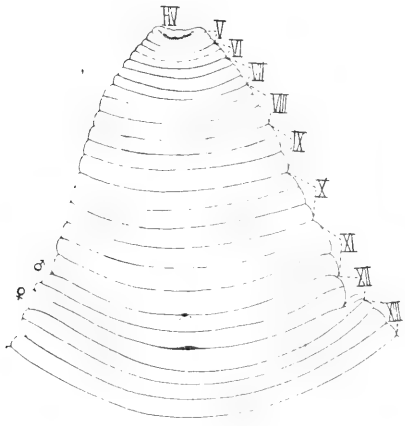


12

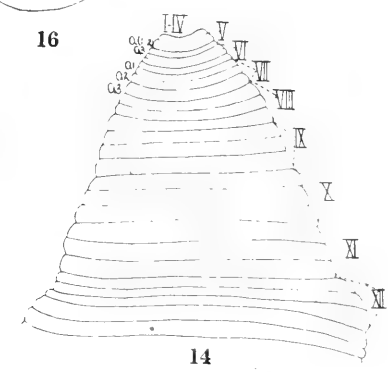


16

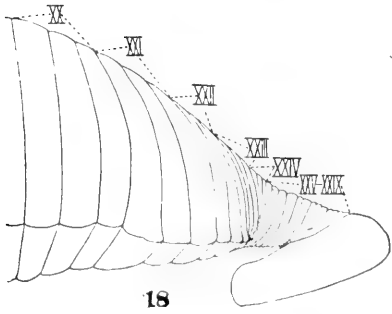
15



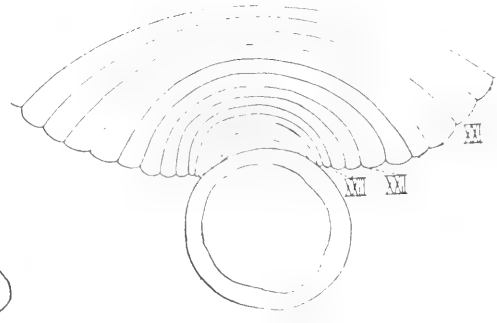
13



14



18



17

Placobdella. Hemiclepsis.

PLATE III.

Actinobdella inequiannulata.

Fig. 19. The external morphology of the dorsal surface. Somites XIII-XXI are omitted as they are precisely similar to those immediately preceding and following them. The furrows are drawn more regularly than they are in nature. x 35.

Fig. 20. A small portion of the margin of the caudal sucker, viewed from within, showing four of the papillæ. The gland ducts are stippled and the muscles are represented by lines. x 130.

Piscicola punctata.

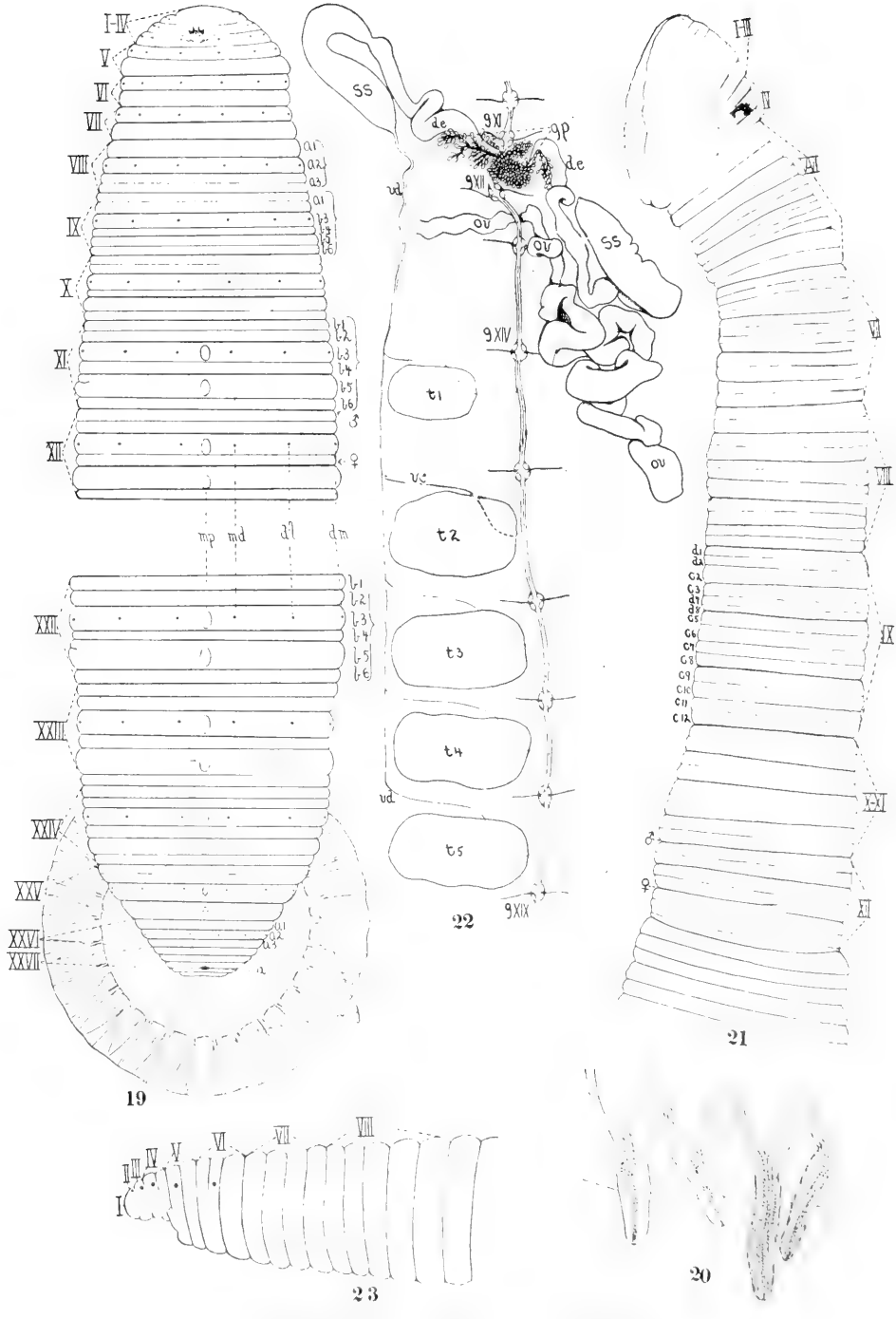
Fig. 21. The first twelve and one half somites seen from the left side, showing the annulation as it appears in a well extended example. The limits of the somites anterior to VII and of X and XI are open to some doubt. x 35.

Fig. 22. The dissected reproductive organs seen from the dorsal side. The testes of the right side and the ovary of the left side are omitted. The left spermduct is drawn forward to display its parts more fully.

de.....Ejaculatory canal of the spermduct.
gp.....Prostate gland.
ov.....Ovary.
ss.....Sperm sac.
vd.....Vas deferens
ve.....Vas efferens
tl-t5 ....Testes of the left side

Hæmopis lateralis. x 5.

Fig. 23. Lateral view of the first eight somites, showing the annulation and eyes of the left side.



Actinobdella. Piscicola. Hæmopis.

PLATE IV.

Macrobdella decora. x 5.

Fig. 24. Dorsal view of the anterior nine somites showing the annulation, sensillæ and metameric color features. The lightly stippled blotches are red and the heavily stippled ones are black.

Fig. 25. Dorsal view of the posterior four trunk somites and sucker.

Hæmopis grandis.

Fig. 26. Dorsal view of the anterior eight somites. X 5.

Fig. 27. Ventral view of the anterior eight somites. X 5.

Fig. 28. Dorsal view of several posterior somites. X 3.

Hæmopis plumbeus. x 3.3.

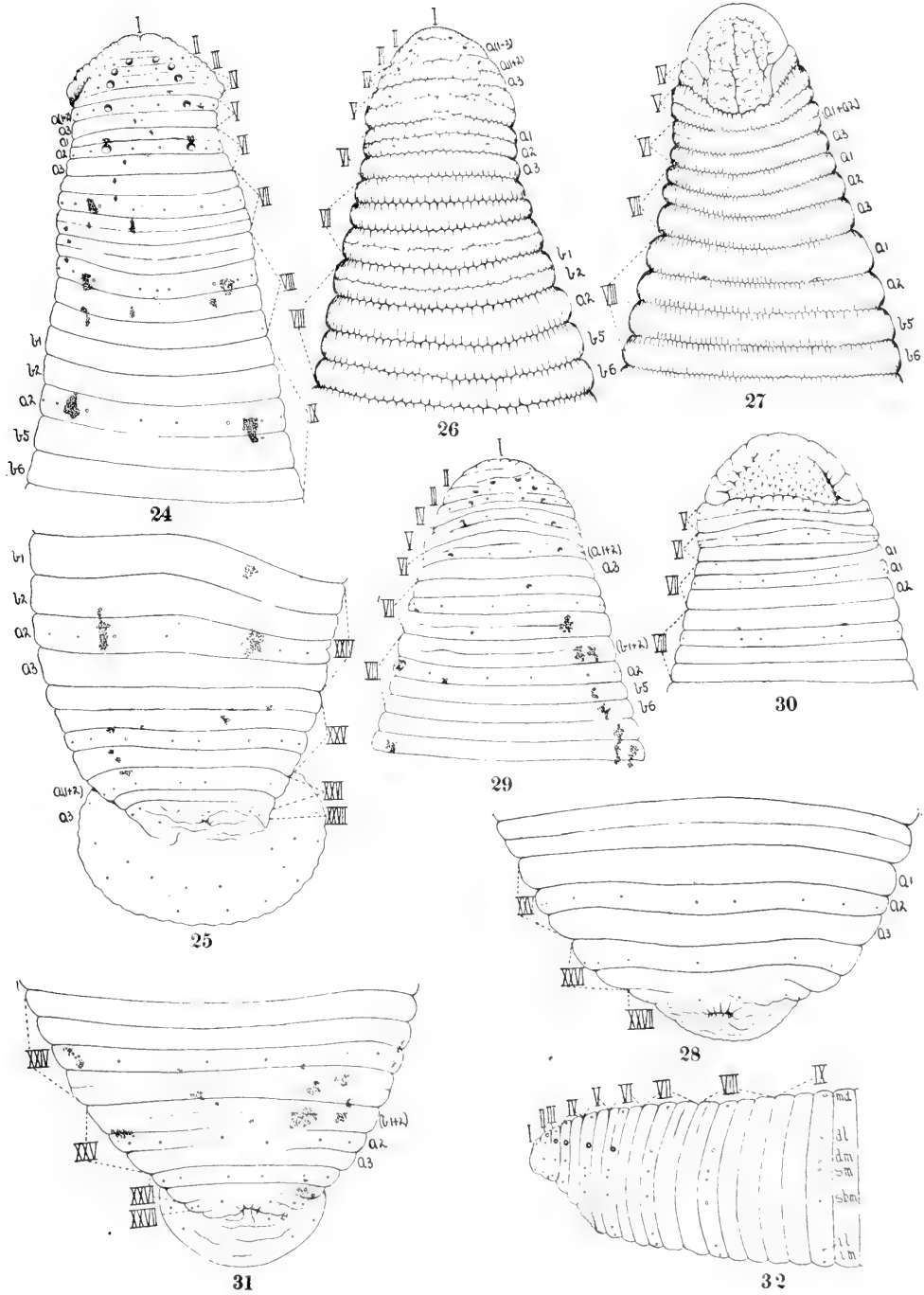
Fig. 29. Dorsal view of the anterior eight somites, showing metameric sensillæ and black blotches.

Fig. 30. Ventral view of the anterior eight somites.

Fig. 31. Dorsal view of several of the posterior somites.

Hæmopis marmoratus. x 5.

Fig. 32. Lateral view of the anterior end, showing the annulation and metameric sensillæ.



Macrobdella. Hæmopis.

PLATE V.

Dina parva. x 22.5.

Fig. 33. Dorsal view of the first nine somites, showing the annulation.
Fig. 34. Dorsal view of several posterior somites, showing the annulation.

Nephelopsis obscura. x 5.

Fig. 35. Dorsal view of the first nine somites, showing the annulation.
Fig. 36. Ventral view of the first nine somites.

Hæmopis grandis. x 3.

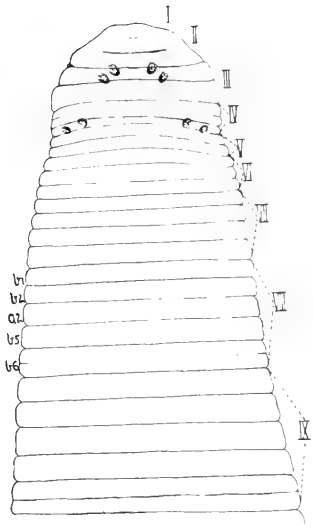
Fig. 37. Dorsal view of the characteristic portions of the reproductive organs dissected out. The right sperm sac and the epididymis have been somewhat displaced to better expose the vagina &c.

at.....Atrium
de.....Ejaculatory canal of the spermduct
ga.....Albumen gland
gp.....Prostate gland
odc.....Common oviduct
ov.....Ovary
ss.....Sperm sac
t1, t2.....Testes
va.....Vagina
vd.....Vas deferns

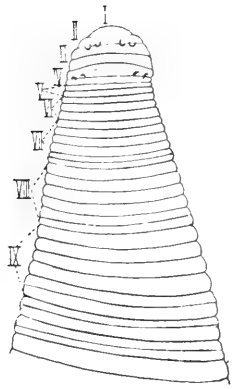
Macrobdella decora. x 4.

Fig. 38. Dorsal view of the reproductive organs somewhat dissected out.

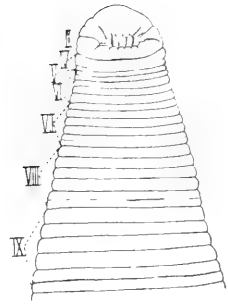
cgl.....Copulatory glands
od .....Oviduct
os .....Egg sac
Other letters as for figure 37.



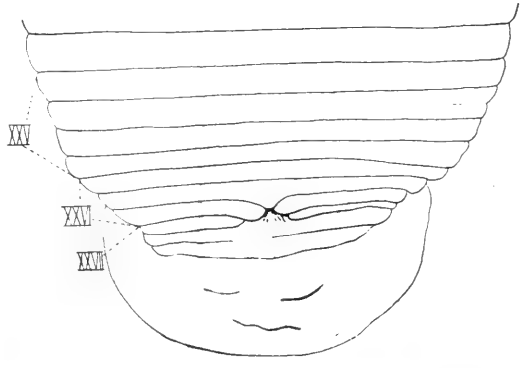
33



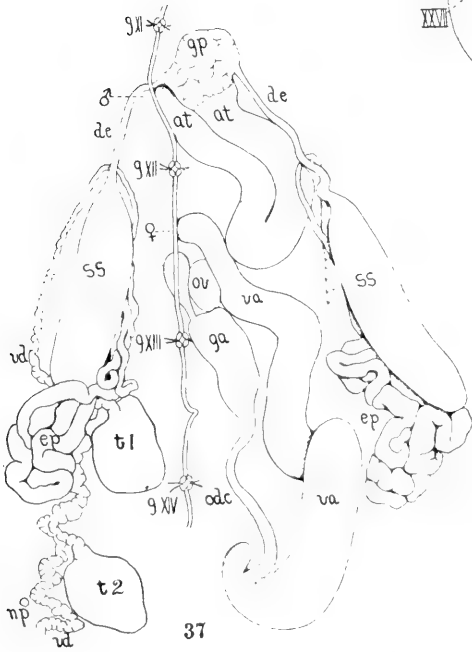
35



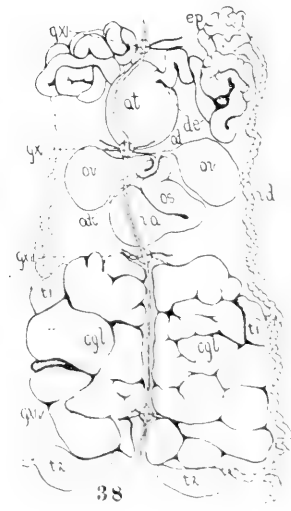
36



34



37



38

Dina. Nephelopsis. Hæmopis. Macrobdella.

PLATE VI.

at .....Atrium
de.....Ejaculatory canal of the spermduct
of.....Closed end of ovarian sac
ov.....Ovary or ovarian sac
p.....Right prostate horn of the atrium
ss.....Sperm sac
t .....Testis or testes sac
vd.....Vas deferens
♀.....female genital orifice

Erpobdella punctata. x 7.5.

Fig. 39. Dorsal view of the dissected reproductive organs. All the testes, the spermduct on the right side and the ovary on the left side have been omitted.

Nephelopsis obscura. x 5.

Fig. 40. Dorsal view of the reproductive organs. Only about one half of the testes of the left side of somite XVIII is shown. The ovary of the left side and all of the testes and most of the vas deferens of the right side have been omitted.

Dina parva. x 10.5.

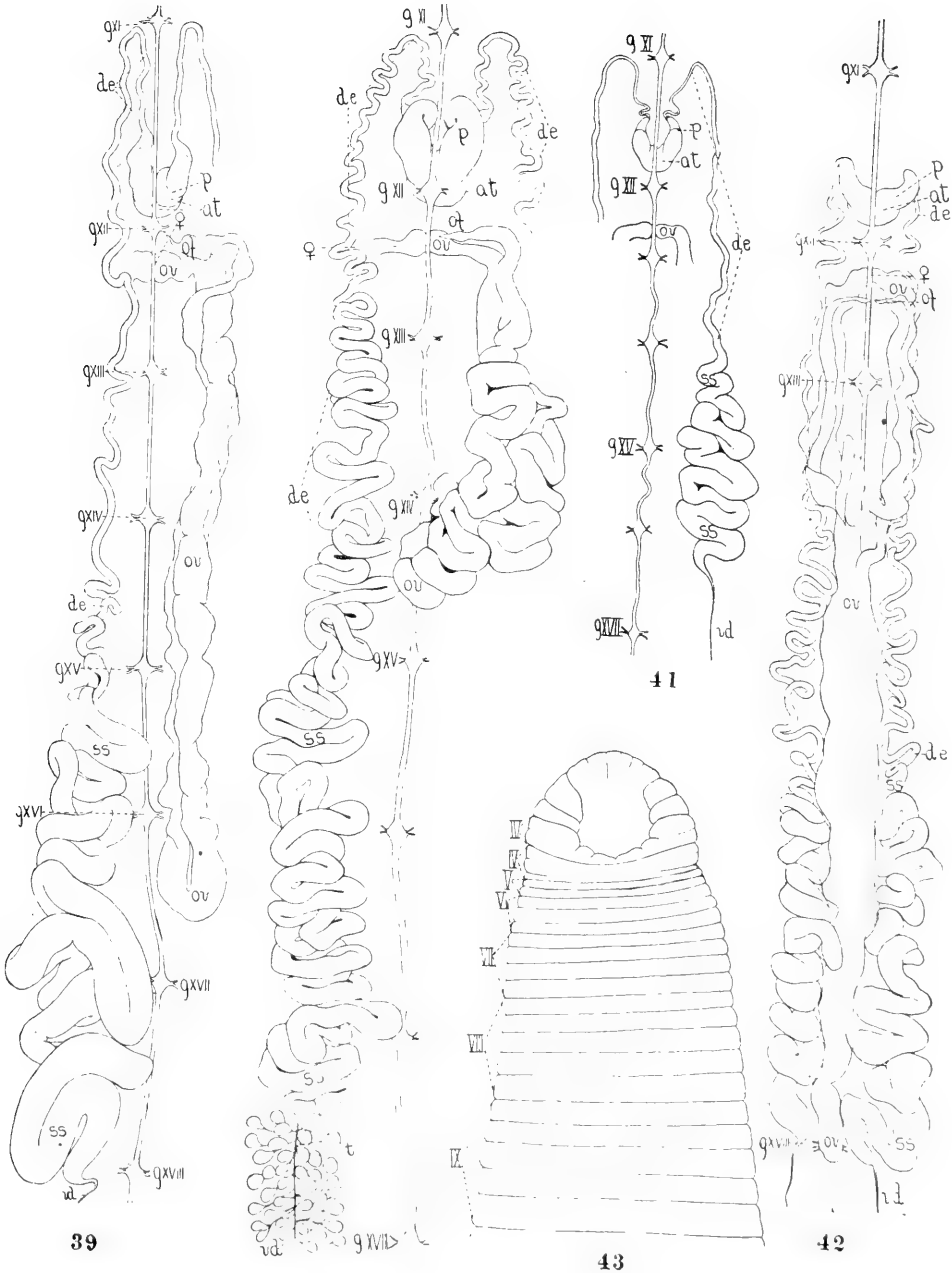
Fig. 41. Dorsal view of part of the reproductive organs.

Dina fervida. x 7.5.

Fig. 42. Dorsal view of the reproductive organs. The testes and collecting portions of the vasa deferentia are not shown.

Dina parva. x 22.5.

Fig. 43. The annulation of the anterior nine somites as seen from the ventral side.


39
40
41
42
43
Erpobdella. Nephelopsis. Dina.

INDEX

The figures in boldface refer to the pages on which the descriptions are begun.

The Roman numerals in parentheses refer to the plates.