The Leeches of Japan.

By

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With Plates XVII, XVIII, XIX, XX, and XXI.

PART I.

THE TEN-EYED LEECHES, OR THE HIRUDINIDÆ.

The material for a study of the Leeches of Japan, including the land, freshwater, and marine Leeches, was collected during my connection with the University of Tokio (1879—1881). The coloured drawings were executed by a young Japanese artist, Mr. Nomura, who has spared no pains in making them exact copies of the living objects. Attention to the minutest details, infinite patience, a trained eye, and a remarkably skilful brush, gave results that are certainly marvels for neatness and accuracy.

For the assistance of Mr. Nomura I am indebted to Mr. Kato, president of the University; and for this and other aid my hearty thanks and grateful appreciation are due.

The ten-eyed Leeches, embracing Hirudo, Aulostoma, Hæmopis, Macrobdella, and some other genera, form a natural division of the Leech tribe, which may, for the present, be conveniently called the Hirudinidæ. The remaining families, the Nephelidæ, Clepsinidæ, Branchellidæ, Branchiobdellidæ, will be treated in separate parts.

The part here presented embraces a description of the Land Leech, the Medicinal Leech, and three species of toothless

Leeches, which form together a new genus (Leptostoma[1]); and a comparison of a few Asiatic, European, and American forms.

A considerable portion of the paper is devoted to a comparative study of the different genera, with a view to finding a more satisfactory basis for classification than has hitherto been employed.

It has been found that all the Hirudinidæ agree in having twenty-six somites represented between the first pair of eyes and the acetabulum; and a careful study of the annular composition of the somites in different genera has revealed a law of abbreviation which holds true of both ends of the Leech. The extent of this abbreviation, which consists in the suppression of from one to four of the less important rings in the extreme somites, furnishes one of the best means for distinguishing genera and species, and at the same time gives us a key to their phylogenetic relationship.

A prominent place has been given to the Land Leech, one of the most interesting and instructive forms, and one which has hitherto received very little attention. An attempt has been made to arrive at satisfactory views respecting its origin and affinities; and some general conclusions, based on a comparative study of a considerable number of species from different countries, have been offered in advance of a monograph now in preparation, which will treat of the entire family.

The Medicinal Leech has been compared with species obtained in Saigon, Singapore, Java, Ceylon, Naples, Sweden; and the genus Hirudo defined with the precision required to make it a convenient standard of comparison.

Internal structure has been dealt with to a limited extent; and some interesting facts, especially in relation to the nephridial organs of the Land Leech, have been obtained.

One of the most important points made clear in the course of the paper is the existence of from twelve to fourteen sense-

[1] In a preliminary paper ('Proc. Amer. Acad. Arts and Sci.,' vol. xx, Sept., 1884) I have used the name Microstoma, not being aware at the time of writing that the same name was already in use,

organs on the first ring of each complete somite, and the serial homology of these with the eyes.

In a postscript I have given the results of a histological study of these sense-organs, and considered the question of their function.

The Land Leech.

The Land Leech has long been known to naturalists, but chiefly through reports of a non-scientific character. The burden of the story so often told by travellers, missionaries, and army officers returning from the East, especially from Ceylon and the Himalayas, is that the land Leech is a bloodthirsty little pest which often makes itself extremely troublesome to both man and beast. An army surgeon has reported several cases in which men have been made cripples by their bite; and an old authority, Bosc, has given wide circulation to the assertion that persons asleep have sometimes been attacked by these creatures in such numbers that death has ensued. Naturalists on collecting tours have sometimes found the woods so thickly settled by these little bloodsuckers that they could save themselves only by beating a very hasty retreat. A whole battalion of English soldiers, according to report, were once driven out of the woods by such overwhelming numbers of leeches that facing them was found to be quite impossible. They advance with such astonishing rapidity that some observers have been led to believe that they can actually spring from the ground, and have therefore given them the name of "jumping Leeches."

As an example of what has been written on this subject, the following remarks by old Robert Knox[1] are introduced:

"In dry weather none of them appear, but immediately upon the fall of rains, the grass and woods are full of them. These Leeches seize upon the legs of travellers, who, going barefoot, according to the custom of that land (Ceylon), have them hanging upon their legs in multitudes, which suck their blood till their bellies are full, and then drop off. They come

[1] 'Historical Relation of the Island of Ceylon,' pp. 48, 49, 1681.

in such quantities that the people cannot pull them off so fast as they crawl on; the blood runs pouring down their legs all the way they go, and it is no little smart neither; so that they would willingly be without them if they could, especially those that have sores on their legs; for they all gather to the sore."

The tales of bloody encounters narrated by Hooker, Hoffmeister, Semper, and many others, have given the Land Leech an odious reputation; and such accounts are responsible for the prevailing notion that the creature is repulsive in appearance as well as fierce in behaviour. The brief accounts that have appeared since the time of Knox, not including the more recent descriptions by Tennent, Schmarda, and Grube, have nearly all come from persons who knew the Land Leech only as a loathsome pest. From the popular standpoint, it must be admitted that the character of the Land Leech has little to recommend it and much that is calculated to inspire disgust. On the other hand, from the standpoint of the zoologist, it may be said that no other member of the whole class of Leeches can lay higher claims to our attention and interest. Myriads of these Leeches are certainly able to give the intruder into their haunts a reception that would leave a lasting, and very likely a painful, impression. But when we reflect that the very traits which render them so irresistible in attack and so offensive in character, furnish unmistakable evidence of the severity with which their energies have been taxed in the struggle for existence; and that by virtue of these traits they have been preserved and have far outstripped their nearest relative, the freshwater Hirudo, we are prepared to admit that their energy, voracity, pertinacity, dexterity, and swiftness in attack call for admiration rather than disgust, and that their peculiarities of structure, mode of life, geographical distribution, and ætiology are subjects quite worthy of careful study.

The geographical distribution of the Land Leeches, of which about a dozen species are known to me, is somewhat more limited than that of the Land Planarians. They are found in abundance in the lower ranges of the Himalayas, where the upper limit of their vertical distribution is said to be not less

than 11,000 feet above the level of the sea (Hooker). They are very common in the damp hilly districts of Ceylon, where, according to Schmarda, they become less numerous at elevations above 4000 feet. Thunberg and A. B. Meyer have met with them on the slopes of Java; and Dr. C. Ph. Sluiter has also collected them in this island, and has furnished me with specimens obtained on the Preanger mountains and in the neighbourhood of Batavia. Marsden found them in Sumatra; Meyen, Semper, and Meyer, in Luzon; Semper, in Mindanao and the Pelew Islands; Knorr, in Japan; Meyer, in New Guinea, and Celebes (Minahassa); Mr. Haswell, in New South Wales and Queensland; and Gay and Philippi, in the southern provinces of Chili. Mr. Jijima and Mr. Sasaki found them very abundant on mountains in the central part of Japan; and I have collected them on a mountain near the eastern coast (Suberi-yama, Hakone). Through Mr. Trimen and Mr. Ward I obtained specimens of the Singhalese species from the botanical garden at Peradeniya, near Kandy; and I collected large numbers of them in the plains, at a place called Kesbawa, about twelve miles from Colombo. Quite recently Kennel has reported a Land Leech from Trinidad.

Although the stray notices and remarks on the Land Leech that have appeared since the time of Knox are sufficiently numerous to make a good-sized volume, only the few pages written by Emerson Tennent,[1] Ludwig Schmarda,[2] and Ed. Grube,[3] have any permanent scientific value. Only two species have been described, and I find no allusion to the Japanese species beyond the simple statement of Grube (2 *a*, p. 59) that it was seen by Knorr.

[1] Tennent, (*a*) 'Ceylon,' 4th edition, i, pp. 302—5, London, 1860. (*b*) 'The Natural History of Ceylon,' pp. 479—483, London, 1861.

[2] Schmarda, 'Neue Wirbellose Thiere,' &c., i, 2nd half, Leipzig, 1861.

[3] Grube (*a*) "Landblutegeln aus Südaustralien," 'Jahresbericht der Schlesischen Gesellschaft,' p. 66, 1865. (*b*) "Landblutegel," same 'Jahresbericht,' p. 59, 1856. (*c*) "Anneliden,' 'Reise der Oesterreichischen Fregatte Novara um die Erde in den Jahren 1857—59,' 'Zool. Abth.,' 3, vol. ii, p. 41, Wien, 1868.

Hæmadipsa, Tennent (1861).

Hæmadipsa, Tennent, 1861. Hæmopis, Schmarda, 1861. Chthonobdella, Grube, 1865, 1868.

The older authors, Bosc, Blainville, Moquin-Tandon, &c., included the Land Leeches in the genus of freshwater leeches, known as Hirudo since the time of Ray. Tennent was the first to introduce a new generic name for the Land Leeches of Ceylon. Schmarda, who claims, erroneously as I believe, that there are several different species in Ceylon, refers them doubtfully to the genus Hæmopis. Diesing follows Schmarda in this respect. Grube was led by comparison of a few species to see the propriety of establishing a new genus, and—evidently in ignorance of Tennent's work—proposed the name Chthonobdella. This name is unquestionably better chosen than Hæmadipsa, but the claim of priority makes it necessary to abide by the latter.

All the Land Leeches cannot well be included in the same genus, as will be shown more fully in a later paper embracing all the species at present known. The Australian species, for which I am indebted to Mr. Haswell, differs from all the other species that I have thus far examined in having only two jaws. The latero-ventral jaws are present, but the median dorsal jaw is entirely absent. This remarkable distinction, taken together with the fact that the genital orifices are separated by seven and a half rings instead of five, as in the case of most other Land Leeches, seems to make necessary the establishment of a new genus, for which I propose the name Geobdella.[1] Hæmadipsa may be reserved for the species found in Ceylon, India, Japan, &c., which have three jaws and five rings between the genital apertures. This genus may be more fully characterised as follows:

Terrestrial. Body, at rest, 2—3 cm. in length, sub-cylindrical, tapering slightly forwards; cephalic lobe, at rest, rounded,

[1] The fact that this name, once applied by Blainville to Trocheta, has now been entirely superseded by the latter name, removes any serious objection to its use here.

but pointed in extension; acetabulum moderately large, round or oval, often obtusely acuminate in front, centrally attached, separated from the body only by a feeble constriction; ocelli in five pairs, the rings bearing the third and the fourth pair not separated by an intervening ring as in Hirudo; the rings bearing the fourth and the fifth pairs separated by two rings; œsophagus with three plications, one dorsal and two latero-ventral; maxillæ three, armed with numerous denticles that increase in size towards the converging anterior ends of the jaws, and curve slightly in the opposite direction; clitellum includes fifteen rings (= three somites); genital orifices separated by five rings; nephridial pores situated in the margin of the body, instead of on the ventral surface, the last pair opening in the constriction that separates the acetabulum from the body, and marked by three minute overarching lobes which are usually paler in color than the rest of the body; segmental papillæ above and below, strongly developed on the dorsal side.

Hæmadipsa japonica,[1] nov. sp., Pl. XVII, figs. 1—7.

Diagnostic Characters.

Body, in extension, nearly cylindrical, tapering gradually towards the head (figs. 3, 5), about 5 mm. in diameter near the acetabulum, and 2 mm. just behind the cephalic lobe; at rest, more flattened, resembling Hirudo in shape (fig. 1). Length, at rest, 20 mm.; in extension, 50 mm.

Cephalic lobe, in extension, very pointed (figs. 3, 5) at rest, rounded (figs. 1, 2).

Acetabulum 6—7 mm. in diameter; circular, or ovato-rotundate, with the narrower anterior end very obtusely acuminate, as in figs. 5 and 9; centrally attached.

Annuli 96.—The first three, bearing the first, second, and third pair of eyes, are obscurely marked; the fourth and fifth

[1] This is not Hirudo japonica auctorum, a name which I have been compelled to ignore, since the meagreness of the description makes identification impossible.

coalesce on the ventral side, and the sixth and seventh are less deeply separated on the ventral than on the dorsal side. The anterior portion of the body generally appears more deeply annulated in extension than at rest.

Buccal Annuli—the fourth and fifth, which unite to form a single ring on the ventral side. They form the lateral and ventral boundary of the buccal aperture.

Genital Apertures.—The male orifice lies between the 29th and the 30th ring, or between the 25th and the 26th, if we begin with the buccal rings and count them as a single ring, as they appear when seen from the ventral side.

The female orifice lies between the 34th and 35th, or 30th and 31st, counting on the ventral side.

Clitellum embraces fifteen rings (three somites), beginning with the 25th and ending with the 39th. These rings have sometimes a dusky hue.

Anus, behind the last annulus, between this and the posterior sucker.

Ocelli, five pairs; the first four pairs arranged in a semicircle on the first four rings, the fifth pair on the 7th ring. The absence of a ring between the rings bearing the third and fourth pairs of eyes is a character in which all the Land Leeches agree, and one which distinguishes them from Hirudo, Hæmopis, and Aulostoma.

Œsophagus has three folds, one median dorsal, and two latero-ventral.

Maxillæ three, corresponding in position with the three œsophageal folds; relatively larger, higher, and thinner than in Hirudo; armed with about ninety denticles, which increase in size in the direction of convergence of the jaws, and curve slightly in the opposite direction. It is thus the inner posterior end of the jaw, which here, as in the Medicinal Leeches, is furnished with the larger denticles. The scar has the form of three converging lines forming about equal angles with one another, precisely as in Hirudo.

Nephridial pores open in the marginal line of the body instead of on the ventral side, as in Hirudo. There are seven-

teen pairs located in the following rings :—12, 17, 22, 27, 32, 37, 42, 47, 52, 57, 62, 67, 72, 77, 82, 87, and 93. Their position is in the hind edge of the ring which precedes the ring bearing the segmental papillæ, as will be seen from fig. 7. The successive pairs are thus five rings apart, with the exception of the last pair. The last pair lie under the anterior of three peculiar lobe-like extensions of rings 93, 94, and 95. These marginal lobes, of which the middle pair are the smaller, are flattened, project obliquely backwards, and rest on the upper surface of the acetabulum. The area immediately surrounding them, as well as the lobes themselves, is paler than the rest of the body.

Segmental Papillæ.—There are twenty rings which, with the exception of the first and the last, project slightly beyond the others (figs. 3, 5, 6, 7) ; and as each (first and last excepted) bears six dorsal and six ventral papillæ, they may be called the papillate rings. The order of these rings, which begin with the 4th and end with the 93rd ring, is as follows :—4, 7, 10, 13, 18, 23, 28, 33, 38, 43, 48, 53, 58, 63, 68, 73, 78, 83, 88, 93. The papillæ are thus borne by every fifth ring except in the anterior portion of the body, where, owing to a reduction in the number of rings to a somite, they occur on every third ring.

Colour.—The dorsal surface is divided into three longitudinal areas, a median and two lateral. The median area is always lighter in colour, and slightly wider than the lateral areas. Two dark brown stripes form the boundary lines between the median area and the lateral areas, and a third dark brown median stripe divides the median area into two halves. The median and wider stripe usually extends from between the first pair of eyes to the anus, and is of nearly uniform width throughout; but in some cases (figs. 6 and 7) it vanishes, or nearly so, on the cephalic end and on a few of the posterior rings. The lateral stripes usually vanish four to six rings behind the fifth pair of eyes, and seldom reach quite back to the posterior sucker. They are besides somewhat more irregular in outline than the median stripe.

There are two pale yellow marginal stripes which vanish before reaching the head, and end rather abruptly behind four or five rings in advance of the rings whose margins are produced into the lobes above described.

The median area is most often a dull yellowish brown, considerably lighter than the lateral areas. In some cases (figs. 1, 6, 7) the median area inclines rather to a reddish hue, the lateral areas being a deeper and richer shade of the same colour. The lateral areas and the somewhat lighter ventral surface are generally sprinkled with fine specks of dark brown. Sometimes, as seen in fig. 5, a feeble tinge of olive is perceptible. The anterior border of the cephalic lobe has a smoky hue which frequently extends to the entire head and anterior portion of the body. The acetabulum is a very pale green or olive above, and smoky brown or olive brown below.

The clitellum is sometimes marked by a deeper shade than the rest of the body (fig. 5).

The ground colour of the Singhalese species (figs. 8, 9) is a rich reddish brown flecked with dark brown, more profusely above than below. The head and posterior sucker show the smoky hue seen in the Japanese species. There are no dark stripes, and, as a rule, no indications of a median area. There are two marginal stripes and one median, all of which are a bright lemon yellow.

Among several hundred specimens I found two or three in which a lighted median area was more or less imperfectly indicated. In all other particulars this species agrees completely with Hæmadipsa japonica.

Habitat.—So far as could be ascertained, the Japanese Land Leech is confined to mountain slopes and ravines, never descending into the low plains, for which reason the Japanese call it the Mountain Leech ("Yamabiru:" yama, mountain, and hiru leech). Specimens were collected by Mr. Jijima from Akihazan, a mountain about 4000 feet high, situated near the centre of the province of Totomi (Enshiū), by Mr. Sasaki on mountains in the provinces of Mino and Iga, between 34° and 36° lat., and by myself on a mountain in

Hakone, called Suberiyama. They are also said to be found on Amaki peak, in the province of Idzu, on the eastern shore.

Habits.—I have never seen the Land Leech of Japan on trees, and I believe it keeps itself habitually on the ground, in the moss, or under damp leaves and loose rubbish. When awakened by the footsteps of man or beast, it quickly appears on the surface, and frequently ascends low plants and occasionally perhaps trees in search of the intruder. They are usually found near the tops of mountains, in damp ravines or dense thickets, where the ground is carpeted with moss and other low plants. During the driest months of the summer these localities are kept moist by mists and showers, and in winter they are sometimes covered with snow. Wild boar and deer frequent these places, and it may well be that these Leeches derive their sustenance in part from such animals. They are much dreaded by the natives, who are accustomed to go with feet and legs bare. They are extremely voracious, and wonderfully rapid in their movements. When once on the person, they take such rapid strides, and cleave with such pertinacity, that it is difficult to remove them without injury. Their bite is so gently executed that it would hardly be felt unless the attention were specially directed to it; but the wound is comparatively deep and the scar often remains for months. They gorge themselves with blood in thirty or forty minutes, and then drop off. During the process a transparent liquid exudes from the skin, which keeps moist both the Leech and the object on which it preys, and even flows away in a few large clear drops. It would not be difficult with a dozen Leeches to collect enough of this fluid for chemical analysis; but I neglected to do this. I think the fluid comes in part from the mucous glands of the skin, and in part from the nephridia. If the moisture be removed by a momentary application of blotting-paper, it is easy to see, on removing the paper, the fluid gathering over the nephridial pores. When the Leech creeps over a dry object it leaves a slimy path similar to that left by land snails. When fully gorged with blood they become sluggish, and do not appear to be averse to going

into water; at least all the specimens which I have fed retired to wet moss and lay wholly or partially covered with water. Hungry specimens confined in a bottle containing a little water remain always above its surface. If dropped into water they do not swim like aquatic Leeches, but sink to the bottom and then creep out again. They are often found in the neighbourhood of small streams, but never in them. Although they have such a decided preference for terrestrial life that they probably never visit the water, even when it is within easy reach, they have not lost the power of living in it for at least a considerable time. One of the Singhalese specimens was kept in water thirty days, and this long submersion resulted in no perceptible injury.

It is interesting to watch the behaviour of hungry specimens confined in a bottle which is kept moist by wet moss at the bottom. They are very quiet so long as the containing vessel iis left undisturbed, but they are very sensitive to any sudden jar or quick movement of the air. They appear to avoid the light and to seek the side least exposed to it. At rest the head and anterior half of the body are often raised as if held in readiness for the attack. If the bottle is opened and a puff of breath blown upon them, they are instantly thrown into a state of great excitement; after a few hasty reaches in different directions have convinced them that the disturber is not in immediate reach, they begin to ascend; and the foremost among them, reaching the rim of the bottle, halt for a moment, standing quite erect and extended as if hesitating in which direction to advance; another puff or a slight jar sets them again in commotion, and they swing to and fro, reaching in all directions for the object of their search. If one attempts to put them back he finds them more than a match; for while trying to thrust one back a dozen others rush on to the hand, and in a few moments are scattered over the body. The best mode of recapturing them is to place over them an inverted bottle, into which they will ascend.

In collecting it is best to use a deep bottle, and to take advantage of their disposition to ascend by keeping it inverted;

for then they will be induced to take a position as far as possible from the mouth, and new specimens may be added without giving those already in time to escape.

In moving about, the cephalic lobe is much elongated, and its obtusely pointed tip appears to be used as an organ of touch. The annuli of the anterior portion of the body are at the same time more prominent and the eyes more protuberant. The mode of progression is the creeping movement common to all Leeches. The head is thrown forward as far as the extended body will permit, and the oral sucker having been fixed the body is drawn up into a vertical loop, and the posterior sucker placed close to the anterior. These looped strides may be repeated with such rapidity as to give the appearance of jumping, but such a movement is plainly impossible in this mode of locomotion.

Comparison of the Land Leech with the Medicinal Leech.—A comparison of the Land Leech with the Japanese Medicinal Leech, which agrees in all its leading features with the continental varieties of Hirudo, affords unmistakable evidence of genetic relationship between the two genera.

In both the land and the aquatic Leech we find that the typical somite embraces five rings; but the two species show a difference of at least five in the total number of rings composing the body. This fact might lead one to suspect that the Land Leech had lost an entire somite; but a careful study of the two cases does not support this view. In Pl. XVIII, fig. 10, I have represented the whole number of rings in the Japanese Medicinal Leech. The total number of rings may be made to vary, apparently at least, according to the mode of counting. Most authors count the rings as they are seen on the ventral side, beginning with the buccal ring (5th and 6th in my figure), and take no account of the fragmentary post-anal ring; thus counted there would be but ninety-five rings, which is the number usually given for H. medicinalis of Europe. Again, if the rings are counted from the dorsal side, leaving the ventral aspect entirely out of consideration, we find that the buccal and post-buccal are each double, and must be counted

as four instead of two. This gives an increase of two rings, whcih, added to the four cephalic rings and the post-anal, gives a total of 102. In a close comparison like the one we are about to make, it will soon be seen that both the dorsal and ventral aspects of the rings must be considered, and that it is advisable to include in our count the rings of the cephalic lobe which are not seen from the ventral side. We are now prepared to take up the comparison of rings with a view to ascertaining precisely which rings have been lost by the Land Leech.

There is a universal tendency among Leeches to a reduction of the number of rings in the somites at both extremities of the body. A glance at the arrangement of the eyes and the segmental papillæ in fig. 10 makes it perfectly evident that the metameric division extends to the very end of the cephalic lobe. The 1st and 2nd somites are each represented by a single ring bearing a single pair of eyes; the 3rd somite has two rings, the first of which bears the third pair of eyes; the 4th, 5th, and 6th somites include each three rings, the fourth and fifth pairs of eyes being borne on the first rings of the 4th and 5th somites. Behind there are three somites of two rings each and then a somite of three rings. The remaining somites have each five rings. In fig. 6, in which the relation of the eyes to the segmental papillæ is very satisfactorily shown, we find exactly the same number of abbreviated somites as in the corresponding portion of the Medicinal Leech; and the reduction in the number of rings is precisely the same, except that one ring is missing in the 3rd somite, in consequence of which the third and fourth pairs of eyes are on contiguous rings instead of being separated by a single intervening ring as in fig. 10. The cephalic lobe has simply lost a single ring, which bore no eyes, and which could therefore be dropped to the advantage of those possessing a higher functional value, since the fourth pair of eyes could thus be added to the semicircle of the more important eyes. In dropping this ring the Land Leech has advanced one step in the well-trodden path of development pursued by its aquatic progenitors. The course of progress may be briefly defined as

centripetal abbreviation, the maximum limit of abbreviation or concentration appearing first of all in the most extreme somites, and advancing from these, step by step, to those that lie successively nearer the middle of the body. Allowing that abbreviation progresses centripetally, it is easy to see what ring, if any, is destined to disappear next. The next step for the Medicinal Leech is to drop the eyeless 4th ring; and for the Land Leech, first the anterior and then the posterior eyeless ring now separating the fourth and fifth pairs of eyes.

That every step thus far taken in this direction has been beneficial, appears evident enough from the fact that the eye-bearing rings have been retained and functionally improved in proportion to the number of the less important eyeless rings sacrificed. These rings have been still further advanced by transverse concentration, the more important elements being brought into closer order and strengthened at the expense of the parts eliminated. The 1st ring in the Land Leech, leaving out of consideration the thin, lighter-coloured margin, is represented by two large eye-bearing plates; the 2nd by two slightly smaller eye-bearing areas and two still smaller median areas, bearing segmental papillæ, or incipient eye-spots; the 3rd, by two similar ocellated areas and eight small interposed areas; the 4th, by two still smaller ocellated areas and six small intermediate areas; and the 7th, by a row of small areas in two of which are seen the posterior pair of eyes, which are considerably smaller than those of the preceding rings. The only incongruity in all this with the view here taken lies in the fact that the third ring has a larger number of intermediate plates or areas than the fourth, which is the reverse of what we might have expected. The arrangement of these areas, however, suggests an explanation of the difficulty. They form a single transverse row which becomes double at the two ends adjoining the ocellated areas. The most natural way of accounting for this duplicity is to assume that two of these areas are remnants of the ring that has disappeared between the third and the fourth pair of eyes.

With respect to the three somites which follow the three cephalic somites, it should be noticed that, although the number of rings in each is the same, they do not exhibit the same degree of concentration and development. The 4th somite is represented on the ventral side by the coalesced buccals and the 6th ring; and on the dorsal side the first buccal (4th ring) is composed of fewer areas than the succeeding rings. The difference between the 5th and 6th somite is slight on the ventral side, but well marked on the dorsal side by the presence of the fifth pair of eyes in the former. Thus the head and anterior end of the body of the Land Leech, especially in comparison with the corresponding portions of the Medicinal Leech, plainly illustrate an order of events which may be called the law of centripetal abbreviation; and at the same time they show a strict correlation between the grade of development and specialization and the degree of abbreviation.

Remembering that the 4th ring of the Medicinal Leech is wanting in the Land Leech, it becomes very easy to identify the rings of the latter with those of the former, and to see that the sexual orifices are situated between homologous rings in the two cases.

Comparing now the hind end of the body of the Land Leech with that of the Medicinal Leech, we find that the direction of abbreviation is here also centripetal. In fig. 10 we find twenty-six somites, of which six anterior and four posterior are abbreviated; while in the Land Leech there are, apparently, only twenty-three somites, of which six anterior and one posterior are abbreviated. In both cases then there are six abridged somites followed by sixteen unabridged; and this leaves only four rings in the Land Leech to offset nine in the Medicinal Leech. There can be but little doubt that the first twenty-three somites correspond in the two species; and this being assumed, we may inquire how far the remaining posterior rings can be identified. The four posterior rings of the Land Leech (fig. 7) appear at first sight to represent a single somite; but this view is rendered doubtful by the fact that no somite of four rings occurs in Hirudo. An examination of a large number of Land

Leeches has enabled me to identify at least three of the four rings. I find that segmental papillæ are sometimes quite distinct, not only on the 93rd ring, as shown in the figure, but also on the 94th and 95th. I have not detected any satisfactory traces of these papillæ on the 96th ring, which is the last and most rudimentary of all the rings. The discovery of papillæ on the 94th and 95th, not only in this species, but also in the Singhalese and the Australian species, makes it certain that the four posterior rings do not represent one somite, but at least three, which would raise the total number to twenty-five. As the 93rd, 94th, and 95th rings each represent a somite, it is more than probable that the 96th ring represents a remnant of the papillate ring of the 26th somite. The rings may then be identified as follows:

93rd ring (Land Leech)	=	94th (Medicinal Leech).
94th „ „	=	97th „
95th „ „	=	99th „
96th „ „	=	101st „

Thus five rings have been lost behind and only one in front. The loss at the anterior end is correlated with a higher development of the sense-organs; at the opposite end, with the enlargement of the acetabulum and the hind end of the body. At both extremities the sacrifice of rings have been restricted to the less important; and it is plain that the less specialized rings of the hind end have been the first to disappear. It is the hind end of the body that has undergone the greater changes in adaptation to life on land.

In abandoning aquatic life, the Land Leech became restricted to one of the two modes of locomotion open to it while living in the water; henceforth the practice of swimming was discontinued, while that of creeping was enormously increased to meet the requirements of the new conditions of life. The result was that the ability to swim was finally completely lost, while that of creeping was immensely improved. Adaptive changes in size, form, and proportions advanced pari passu with the cultivation of one mode of locomotion to the exclusion of the other. The centre of gravity travelled backward

from the central position required for maintaining the equilibrium in swimming to a point nearer the posterior sucker, keeping pace with the gradual concentration of muscular power in the sucker and posterior end of the body. The body became more cylindrical, the acetabulum and the posterior extremity stouter, thus enabling the Leech to poise on this end with great ease when reaching about for its victim.

The Segmental Papillæ.—In the foregoing comparison of the rings and somites of the land and the aquatic Leeches, attention was called to the position of the eyes and the segmental papillæ; and this leads us to a point of considerable importance, namely, the significance of the papillæ.

In the Land Leech, the epidermis is broken up into quadrangular and polygonal areas; and the larger areas are the seats of the eyes and the papillæ. The number and arrangement of these areas on the cephalic lobe are very regular and uniform in different individuals of the species. Behind the head the areas are arranged in transverse rows corresponding in diameter to the thickness of the rings. This division into areas extends to every part of the Leech, and gives the surface that rough appearance which Grube has described as "granular." In addition to the segmental papillæ, which, from their size and metameric arrangement, are very conspicuous (figs. 6 and 7), there are numerous smaller papillæ which amount to only slight rounded elevations situated at the centre of the areas which are not occupied by the eyes or the segmental papillæ. In the posterior region of the body the segmental papillæ are conical in form, with rounded summits which are pale yellowish white and translucent. At the centre of the summit there may be seen a minute dot of a plumbeous hue, which has the appearance of a pore. Sections show that there is no pore, and that the dot is merely a minute unpigmented portion of the solid papilla. Towards the head the papillæ become more and more flattened; but their lighter colour and the larger size of the lead-coloured central dots make them quite distinct. Owing to the bilaterally symmetrical arrangement of these papillæ on the first ring of each somite, there are as

many transverse rows as somites, and as many longitudinal rows as papillæ in a single ring. The longitudinal rows may be designated according to position, as median and lateral. The two median rows are the most prominent, and are placed somewhat nearer the lateral dark-brown stripes than the median stripe; the two inner lateral rows are located just outside the lateral stripes, and the two outer lateral rows just inside the marginal yellow stripes. Thus each of the three broad longitudinal areas of colour is marked by two rows of papillæ.

In the aquatic Leech (figs. 10, 11, 18) we find six rows of spots which are plainly homologous with the segmental papillæ of the Land Leech, although smaller and only slightly raised into papilla-like protuberances.

On the ventral side of both the land and the aquatic Leech are also found six rows of these segmental papillæ or spots; but here they are so feebly developed that they might be overlooked. They are placed on the rings that bear the dorsal rows and are similarly disposed.

These segmental spots have been described in various species of aquatic Leeches, but no one has hitherto studied their structure, or offered even a plausible suggestion as to their function. Their arrangement on the dorsal side, as shown in fig. 6, suggests an explanation of their nature, which is corroborated by a study of their histological structure. It is perfectly plain that the fifth pair of eyes occupy the places of two of these spots in the inner lateral rows. It is also easy to trace the median rows into the first pair of eyes. As will be shown more fully in describing the Medicinal Leech, the first pair of eyes must be genetically associated with the two median rows of segmental papillæ; and all the remaining eyes with the two inner lateral rows. According to this view, the eyes and segmental papillæ were, primarily, morphological as well as physiological equivalents; but this does not necessarily imply that they now have the same functional significance. The original segmental papillæ may have represented sense-organs of a more or less indifferent order, among which, in

the course of the historical development of the Leech, a division of labour was introduced, a few at the anterior extremity becoming specialised as organs of vision, the rest either remaining in their early indifferent condition or becoming specialised in some other direction.

It seems more probable, however, that the segmental papillæ are incipient eye-spots—visual organs in statu nascendi—and that the eyes are organs of the same nature, only structurally improved and functionally exalted.

The Structure of the Eyes and Segmental Papillæ.—If any such relationship exists between the eyes and the segmental papillæ as is indicated by their correspondence in position, we should expect to find some important resemblances in their structure and composition. As this subject will be considered in detail in a later paper provided with illustrations, I shall here call attention only to the more important points.

The eye of the Land Leech, like that of the aquatic Leech, is formed of large clear cells ("eigenartige helle Zellenkörper," of Leydig), which are usually regarded as a corpus vitreum, surrounded by a thick layer of pigmented cells. The epidermal layer covering the eye is composed of closely packed columnar cells, which are not perpendicular to, but inclined towards the centre of, the convex outer surface of the eye. This epidermal cap is further distinguished from the epidermis elsewhere in being entirely free from pigment. The cell nature of the large clear bodies forming the central portion of the eye has been denied by Ranke, on the ground that no nuclei had been discovered in them by himself or other authors. My sections, however, demonstrate the existence of nuclei in these bodies. The nuclei are extremely small and usually situated very near the outer side of the cells, close to the pigmented layer, and are therefore easily overlooked. Within each of these clear cells there is found a very peculiar white corpuscle which never stains. Leydig represents this body in a few cases as a complete ring, but in most cells as an imperfect ring opening towards the base of the eye. In the

Land Leech this body is band-shaped and bent in various directions, so that in section it often appears to consist of several separate pieces, which may be straight, bent, or looped. The optic nerve does not enter the eye at its base, but at some little distance from the base on the anterior side.

The clear central cells of the eyes are very remarkable elements, differing in their general appearance and structure very conspicuously from any cells that have hitherto been discovered in other parts or organs of the Leech. But I have found that these peculiar cells—from two to four or more in number—are also present in each of the segmental papillæ of the ventral as well as of the dorsal side, in both land and aquatic Leeches. I have succeeded in tracing a nerve up to these cells, without, however, finding any connection. As before stated, the lead-coloured dots at the centres of the segmental papillæ are free from pigment and transparent like the epidermal cap of the eye. The only important difference in composition between the eyes and the papillæ is the absence of the pigment layer in the latter. This difference is not easily reconciled with the view that these papillæ are ocular in character. Still the fact that they are much larger on the dorsal than on the ventral side, and the presence of those "peculiar (sense ?) cells" situated just below a window-like opening in the surface pigment, as well as their obvious serial relationship with the eyes, favour such an interpretation. The evidence pointing in this direction is, perhaps, somewhat weakened by the fact that those same clear cells, which have hitherto been regarded as peculiar to the eyes, are found alongside the nerves running to the "goblet-shaped" sense-organs located in the margin of the cephalic lobe. The presence of these cells in the segmental papillæ cannot therefore decide the question of their physiological significance. It is quite certain, however, that these papillæ are not respiratory organs, as suggested by Ebrard. Their position is not in favour of their being organs of taste or smell; and their structure is opposed to the idea that they are either auditory or tactile organs.

The distribution of the large clear cells, each with its enigmatical band-shaped corpuscle and minute nucleus, among the different sense-organs, appears to show that they are sense-cells, and to throw considerable doubt on the commonly received opinion that they function merely as a corpus vitreum in the eye of the Leech. The fact that the optic nerve, after penetrating the eye, can be traced for some distance along its axis between these cells is in itself sufficient evidence that they cannot be explained as a purely dioptric apparatus (cf. Postscript).

The Nephridia.—The nephridial organs agree in the main with those of the Medicinal Leech, which have been so well described by Bourne,[1] but differ from them in three important particulars. 1. The efferent ducts terminate in the margin of the body, instead of on the ventral surface at some distance from the margin. 2. The vesicles are much larger than in the aquatic Leech. 3. The three pairs of vesicles located within the region of the clitellum are lined with very thick cubical cells which form irregular folds, projecting into the cavity, while they are elsewhere lined with thin pavement epithelium.

In the European Hirudo, the vesicles are oval sacs, the larger diameter of which is only about twice that of the testicular sacs, and are located just outside the vasa deferentia, the successive pairs alternating with the testes. In the Land Leech the vesicles are capacious sacs holding the same serial relation with the testes, and lying partly beneath, but mainly external to, the cæca of the stomach. As they are opposite, and continuous with, the cæca, their shape conforms in the main to that of these appendages, and hence must vary according to the degree of distension of the latter. In a horizontal section of the Leech, one of these vesicles is seen to extend in an antero-posterior direction through from three and a half to four rings; while in Hirudo it bridges only two rings, less than

[1] A. G. Bourne, (*a*) "On the Structure of the Nephridia of the Medicinal Leech," 'Quart. Journ. Mic. Sci.,' xx, July, 1880, p. 283. (*b*) "The Central Duct of the Leech's Nephridium," idem., vol. xxii, July, 1882, p. 337.

half the somite. In a transverse direction the vesicle has about the same extent, so that its capacity is well nigh equal to that of the undistended cæcum.

It is apparent then that the vesicle here represents a bladder-like reservoir, the capacity of which, relatively speaking, must at the lowest estimate be more than double that of the corresponding part in the Medicinal Leech. I have not discovered any cilia in the vesicle, but I am not prepared to say that they are wanting.

The efferent duct is composed of two distinct portions; the lumen of the inner portion is much larger than that of the outer, and is lined with an epithelium quite like that of the vesicle; the outer portion, which is nearly equal in length to the inner, is lined by an involution of the epidermis, and is supplied with both ring and radial muscle-fibres. The inner portion is furnished with ring fibres alone, which are multiplied in number at its junction with the vesicle, so as to form a powerful sphincter. The course of the comparatively long efferent duct is nearly at right angles to the axis of the body, the inner portion being nearly horizontal, and the outer inclining a little upward to reach the margin.

The glandular part of the nephridium is somewhat larger relatively than in Hirudo, lies in front of the vesicle, and opens into it by a funnel-shaped orifice. The "vesicle duct" passes directly into the smaller "central duct," which, after perforating a convoluted chain of shells, enters the more massive portion in which the cells are arranged radially. According to Bourne, the vesicle duct in Hirudo is "formed by numerous cells, several cells surrounding the lumen of the tube." In the case of the Land Leech the vesicle duct is formed of a single chain of cylindrical cells, each cell entirely surrounding the lumen. The chief difference then between this duct and the adjoining portion of the central duct is its greater lumen.

It remains to find some explanation for the extraordinary size of the nephridial vesicles. It is now generally admitted that the nephridia are renal organs; and this view of their function has tended to bring into discredit the idea that the

liquid secretion of these organs serves any useful end in the economy of the Leech.

Moquin-Tandon[1] designates the vesicles as "poches de la mucosité;" and after alluding to the old belief that they were organs of respiration (Schlacht, Bibiena, Thomas, Dugès and Audouin), states that "on les regarde aujourd'hui, avec raison, comme réservoirs de mucosité."

Ébrard,[2] who gives a detailed account of the formation and deposit of the egg-case, claims that the superficial portion of this capsule, which has a spongy texture, is formed from the secretion of the nephridial organs ("anses mucipares") which lie before and behind the clitellum, while the internal portion is the product of the subcutaneous glands of the clitellum. Ébrard thus regards the nephridia as organs of secretion comparable to the colleterial glands of insects ("gland sérifique") and bases this view on the following observations:

"Ayant ouvert, ai-je déjà dit, une Sangsue qui se disposait à poser un cocon et qui commençait à former de l'écume, je trouvai que toutes les poches de la mucosité étaient très-dilatées et remplies de liquide. Chez une autre Sangsue, au contraire, que j'ouvris alors qu'elle était entourée d'écume de toutes parts et immobile, les poches de la mucosité étaient toutes vides, sauf celles de la ceinture. On reconnaissait qu'elles venaient d'être distendues. Je me crois donc autorisé par ces observations, à penser que le liquide mucilagineux qui, agité par la tête de la Sansgue, se convertit en écume puis se change en tissu spongieux, est secrété par les orifices des poches de la mucosité."[3]

The fluid enclosed along with the eggs in the capsule is supposed by the same author to come from two sources, namely, the uterus and the nephridial vesicles belonging to the region of the clitellum. That the renal fluid should have two such entirely unlike uses, sharing, on the one hand, with the secre-

[1] 'Monographie des Hirudinées,' p. 129, Paris, 1846.

[2] 'Nouvelle Monographie des Sangsues médicinales,' pp. 79, 117, 119, Paris, 1857.

[3] Loc. cit., p. 119.

tion of the gland-cells of the clitellum the work of forming the cocoon, and serving, on the other, in common with the fluid discharged from the uterus, as reserve food-material for the young, is a supposition neither probable in itself nor well supported by observation. By what means could the Leech gather the renal fluid around the clitellum? And, allowing that this could be accomplished, by what process could the fluid be converted into the spongy substance of the cocoon? That such a transformation requires some explanation is evident from the fact that the fluid does not take the form of a spongy body on other parts of the body. Leuckart[1] has shown conclusively that both the capsule and its spongy mantle are of the same chemical and physical nature; and the manner in which the cocoon is formed leaves little room to doubt that its substance is derived exclusively from the unicellular glands of the clitellum. This is the view taken by Leuckart, Lankester,[2] and, so far as I know, by all the more recent writers.

That the nephridia within the limits of the clitellum concur with the uterus in supplying the fluid contents of the cocoon, seems to me not altogether improbable, in view of the peculiarities of the vesicles of this region in the Land Leech. The only observation in favour of this opinion adduced by Ébrard is the following:—A single Leech was opened at the moment when the capsule was nearly ready for the reception of the eggs; and the vesicles within the clitellum, and within this region only, were found full of fluid; the same vesicles were found empty in another individual that had just deposited a cocoon. Perhaps we shall not show too little respect for an opinion based on a single experiment of this kind, if we venture to express a regret that Ébrard did not, so far as can be learned from his statements, repeat his observation before giving it the importance of a general fact.

In the Medicinal Leech, the fourth, fifth, and sixth pairs of vesicles lie within the sexual girdle, precisely as in the Land Leech; but their structure is the same as that of the vesicles

[1] 'Die Menschlichen Parasiten,' i, p. 684, 1863.

[2] 'Quart. Journ. Mic. Sci.,' xx, p. 304.

lying before and behind this region, and thus their morphological features neither confirm nor contradict the opinion of Ébrard.

In the Land Leech, however, we do find a strongly marked histological difference between the vesicles of the clitellum and those of the rest of the body, and this fact fully warrants the belief that they are in some way subsidiary to the reproductive organs. These three pairs of vesicles open in the 27th, 32nd, and 37th rings, and are thus clearly inside the region of the clitellum, which extends from the 25th to the 39th ring. The contents of these vesicles could easily be discharged into the cocoon, as suggested by Ébrard; but there is at least a possibility that they assist in the formation of the cocoon, and still another that their secretion aids the copulatory process, thus serving an end for which special glands have been provided in the case of Macrobdella.[1]

Under the head of "current statements as to the nephridia," Bourne, after referring to the opinion of Gratiolet and others that the nephridia are secretory, comments as follows:— "Gratiolet considers that they also serve to keep the skin moist while the animal is out of the water, and correlates the greater power the Medicinal Leech has of staying out of water compared with that of the Horse Leech with the larger size of these organs in the former animals. Leydig has shown, however, that unicellular glands open all over the surface of the skin, and these would serve to keep it moist, just as in Land Planarians, the frog, and other terrestrial animals which possess a moist skin. I see no reason to suppose that the nephridia of the Leech have any such mucous function."[2]

Moquin-Tandon and Ébrard have called attention to the fact before mentioned, that when the surface of the Leech is made uncomfortably dry by means of paper or dust, fluid may be seen to gather in small drops corresponding in position with the nephridial pores. This experiment I have often repeated with both aquatic and Land Leeches, and always with the same

[1] Leidy, 'Proc. Phil. Acad. Nat. Sci.,' p. 230.

[2] Loc. cit., p. 285.

result. We have then experimental proof that the Leech can moisten its ventral surface at least with fluid discharged from its nephridia. If the loss of moisture stimulates a Leech to expel its nephridial fluid, the most natural inference seems to be that the act is designed to restore the moisture. I can see no serious objection to the opinion that the nephridia may co-operate with the numerous gland-cells opening at the surface in keeping the skin moist; and I am unable, on any other hypothesis, to find a satisfactory explanation of the peculiar differences between the nephridia of the aquatic Leech and those of the Land Leech. These peculiarities were undoubtedly acquired in adaptation to terrestrial life—a mode of life which, under the most favorable conditions, must inevitably have taxed to the utmost any organs that could furnish moisture or serve as reservoirs. We are not therefore surprised to find the Land Leech provided with more numerous skin-glands and more capacious nephridial vesicles than its nearest aquatic relative.

Allowing that the nephridial secretion may serve the end we have indicated, and remembering that such service would most likely be required when the Leech is scouring about, it is plain that the marginal position of the nephridial pores would present some advantages over the latero-ventral position seen in Hirudo. The various attitudes assumed by the Leech while moving about are such as would favour the spreading of the secretion in all directions, over the dorsal as well as the ventral surface.

Under the head of "habits," I have mentioned that while the Land Leech is engaged in the act of sucking blood, it discharges a limpid fluid in such quantities that it rolls away in several drops. I have supposed that this fluid came from two sources, namely, the mucous gland-cells and the nephridia. Gratiolet appears to have observed precisely the same phenomenon in the Medicinal Leech; and he was of the opinion that the fluid came from the nephridia. As the gland-cells are undoubtedly active when the Leech is thus engaged, it does not seem probable that the escaping fluid contains no admixture of

their mucous secretion; still I am inclined to believe that much the larger part of it comes from the nephridia.

This brings us to the question, whether the nephridial fluid discharged while the Leech is sucking is for the most part secreted ex tempore, as supposed by Gratiolet; or furnished mainly at the expense of the fluid already secreted and held in reserve in the vesicular reservoirs. The following remarks by Gratiolet on this point are highly interesting, although there may be room for doubting their entire accuracy:—

"Lorsque les Sangsues étaient attachées à la peau et avaient déjà absorbé une certaine quantité de sang, je voyais sourdre sur les flancs de l'animal un fluide hyalin qui s'épanchait sur ses côtés et l'entourait fort exactement d'une zone liquide. La quantité de fluide augmentait à mesure que la Sangsue se remplissait de sang. Il s'écoulait par un courant continu, de petits orifices qui donnent issue aux vésicules des anses mucipares.

"Quelle était l'origine de ce fluide? Le sang de l'animal? Mais évidemment il excédait en quantité la masse entière du sang contenu dans ses vaisseaux. Il provenait évidemment d'une autre source, c'est-à-dire du sang étranger, introduit par la suction dans le tube digestif.

"Ainsi, au moment même où le sang est sucé, la Sangsue en sépare les parties les plus liquides, elle le concentre, pour accumuler en plus grande quantité ses éléments nutritifs. Or, les agents par excellence de cette concentration sont les vésicules et les anses mucipares; elles viennent donc d'une manière accessoire en aide aux fonctions digestives.

"Ce rapport est-il le seul? En aucune façon. Elles peuvent aider encore aux fonctions respiratoires en humectant la peau et par conséquent favoriser les excursions que fait un animal essentiellement aquatique dans un milieu aérien, et la faculté que les Sangsues, les Hæmopis, les Aulastomes et les Trochètes ont d'errer sur la terre, est évidemment proportionnelle au développement et à l'activité de ces appareils excréteurs.

"Ainsi, dans la Sangsue médicinale, ils sont très grands et

très vasculaires, or cet animal abandonne spontanément les eaux en plein jour. Ils sont beaucoup moins développés dans l'Aulastome qu'on ne voit guère errer sur la terre pendant le jour, mais seulement à l'aurore ou au crépuscle. . . . .

"Les Hirudinées, qui n'ont point la faculté d'arroser leur peau, n'abandonnent jamais les eaux où elles vivent; telles sont les Nephelis (Erpobdelles) et les Clepsines ou Glossiphonies, qu'on pent conserver indéfiniment dans des vases ouverts."[1]

While I fully concur in the opinion that the nephridia aid the respiratory functions by helping to keep the skin moist, I have found no satisfactory evidence that they assist the work of digestion in the manner indicated above. The quantity of fluid that escapes from the Land Leech during the process of sucking, certainly does not exceed the capacity of the nephridial vesicles, and hence I see no reason to suppose that the more watery and less nutritious portions of the imbibed blood are collected and discharged by the nephridia with a rapidity that would imply a constant current from the "stomach" to the exterior through the nephridial ducts. The vesicles are so placed with respect to the cæca of the stomach that the maximum expansion of the former is correlated with the minimum distension of the latter, and vice versâ; so that if the vesicles are full when the Leech begins to fill itself with blood, their contents would probably be expelled in slow but steady streams issuing at the nephridial pores. As the gradual distension of the cæca would seem to be quite sufficient to account for the escape of the nephridial fluid, it is probable that the muscles belonging to the walls of the vesicles would remain quite passive during the process, their activity being reserved for occasions of need such as might arise during a dry season or in the perambulations of the Leech.

If the vesicles serve the end supposed, it is evident that there must be some correspondence between their size and the

[1] 'Recherches sur l'organisation du système vasculaire dans la Sangsue médicinale et l'Aulastome vorace,' Paris, 1862, pp. 28—30. The same in 'Ann. des Sci. Nat.,' sér. 4, Zool., xvii, pp. 197—199.

power of the Leech to remain out of water; but as these are not the only organs for supplying moisture to the skin, it would be rash to conclude that all those Leeches which are provided with very small vesicles, or with none at all, are incapable of leaving their native element. It is certainly going too far to assert that Nephelis and Clepsine never leave the water, and that they may therefore be kept indefinitely in uncovered vessels.

There are seventeen pairs of nephridia as in Hirudo. The number, position, and external appearance of the reproductive organs agree closely with the same in Hirudo. The histological features of the internal organs will be dealt with in a future paper.

General Remarks.

Only a few general conclusions concerning the origin and distribution of the Land Leeches are here offered, as a fuller discussion of these questions may be best reserved for a paper which will deal with all the species at present known.

There are certain peculiarities of structure common to all the Land Leeches I have examined; such as the absence of an eyeless ring between the two rings bearing the third and fourth pairs of eyes, the marginal position of the nephridial pores, the large size of the vesicles, and the peculiar lobes which cover the posterior pair of pores. These features point to a common origin of species that are now widely separated. It is quite certain that at some period of their genealogical history they exchanged aquatic for terrestrial life. Their nearest relatives are the Medicinal Leeches (Hirudo), all of which, as is well known, are confined to fresh water. At first thought, it would seem somewhat remarkable that an animal so thoroughly adapted to aquatic life as the Medicinal Leech should be able to accommodate itself exclusively to life on land; but when we compare its habits and conditions of life with those of the Land Leech, and look more closely into the nature of the change implied in the exchange of respiratory media, we find little in the transition to excite our wonder. The Medicinal Leech has

the habit of crawling partly or wholly out of the water, when the air is so saturated with moisture that it can venture out without exposing its skin to undue desiccation. Remembering that the respiratory functions in the Leech are performed by the skin, and that, provided this is kept moist, it is capable of drawing its supply of oxygen from damp air, there is little difficulty in understanding how such an animal might become accustomed to living out of water altogether. Such a change would not lead necessarily to the immediate loss of any organs nor to the acquisition of new ones. Certain organs have been compelled to do more work in the Land Leech than they do in the aquatic Leech, and the consequence has been multiplication and enlargement. The skin-glands have become larger and more numerous, and the nephridial vesicles have expanded to bladder-like reservoirs, so that the Leech is still able to keep its dermal respiratory organ constantly moist.

The Land Leeches are mainly confined to islands and continents that lie within the tropics; but the extreme limits of their latitudinal distribution is not much less than 40° on each side of the equator. The highest parallel of N. lat. is touched in Central Japan; of S. lat. in the southern provinces of Chile. Notwithstanding this wide range in latitude, the conditions under which the different species live are remarkably uniform. From the Himalayas to Japan, from Ceylon to Chiloe, they have established themselves in localities that present exceptionally even, and almost identical, conditions of climate. Neither in the most northern nor in the most southern latitudes of their distributional area have they passed much beyond a subtropical environment; and within the tropics, the perennially humid mountain forests in which they have made their homes, shield them from the more severe degrees of heat. In the Himalayan mountains and in Japan they range somewhat above the line at which snow falls annually; but they are most abundant below this line. In Ceylon and most of the remaining countries inhabited by them they are never exposed to snow and ice. The Singhalese species is, however, as I have proved by experiment, capable of enduring a temperature as

low as 7° C. This fact shows that they still retain the hardiness characteristic of Leeches in general.

In Japan the extremes of temperature mark a rather high amplitude; but they are not so far apart as in corresponding latitudes of the neighbouring continent. The surrounding sea and the Black Stream (Kuro-shiwo) are two important factors in determining the climate of Japan; besides giving a milder winter and a cooler summer than are found on the west side of the Japan Sea and the Yellow Sea, they keep the air abundantly supplied with moisture throughout the year. Some idea of the mildness of the winter at Tokio (35½° N.), which lies nearly in the latitude of the localities from which Land Leeches have been obtained, may be gathered from the fact that chrysanthemums appear in October, camellias in December, plum-blossoms in February, and cherry-blossoms early in April. At Tokio the extremes of temperature seldom exceed −35° C. and −7° C. In the thickly wooded, elevated districts inhabited by Land Leeches, the winter temperature will often fall below +7°C., and the summer temperature will fall far below the temperature at the same season in Tokio. During the summer, the Japanese Land Leeches enjoy a moderately cool, moist, and very even temperature; in winter they are often covered with snow, and undoubtedly undergo a winter sleep, as in some parts of the Himalayas.

Their capacity for enduring a temperature considerably below the freezing point, their ability to live under water for at least several weeks, and their restriction to perennially moist climates, all show that they have not departed very far, physiologically, from their aquatic predecessors. The untold ages required to scatter them in so many distant and isolated parts of the earth have sufficed to fix them in terrestrial habits of life; but this life has been offered to them under such easy conditions that they have been able to adopt it without fully surrendering their qualifications for the original mode of life.

According to this view, the Land Leeches are not yet fully emancipated from the conditions of aquatic life, since they

can live on land only where the air is loaded with water. They are not, therefore, to be regarded as the scattered and isolated survivors of a race that has passed the meridian of its career, aed are now verging to extinction, but as animals still on the road to terrestrial life.

Although the distribution of these Leeches is now preponderantly insular, there are unmistakeable indications—at least in the case of the Japanese and Singhalese species—that they have sprung from a continental stock. The close affinities between two species so widely separated as those of Japan and Ceylon are easily accounted for, when we remember the proximity of these islands to the same great continent. There can be but little doubt that they are to be explained on the same general principles that serve to account for numerous other resemblances between the faunæ and floræ of these distant islands. I believe that the progenitors of these two species, and probably all the remaining species, had their headquarters somewhere on the continent of Asia, most likely on the slopes of the Himalayas.

Hirudo nipponia,[1] nov. sp. Pl. XVIII, figs. 10—20.

Diagnostic Characters.

Body has the shape and proportions of the European Medicinal Leech, but is much smaller. Figs. 18 and 20 represent two of the larger individuals, and figs. 12, 14, and 17, three of the smaller ones. The following measurements were taken from one of the larger specimens:—

Length, swimming, 8·5 cm.;		creeping, 10 cm.;		at rest, 3·4 cm.
Width	„	10 mm.;	„	7 mm.
Height	„	3-4 mm.;	„	4 mm.

Greatest width a little behind the middle; tapering from this point towards the extremities, but more anteriorly than posteriorly.

Cephalic lobe rather broad, and well rounded in front, composed of four annuli.

[1] Nippon, the native name for Japan.

Acetabulum 6 mm. in diameter, circular, and centrally attached.

Annuli 102.—The 5th and 6th annuli coalesce on the ventral side; and the same is true of the 7th and 8th. Counting on the ventral side, and omitting all that are not seen from this side, we find only ninety-three annuli. The first would be the 5th and 6th of the dorsal side; and the second, the 7th and 8th. Behind the 93rd, which is the last that can be seen from the ventral side, there are three more to be seen on the dorsal side, the last of which is very imperfectly defined.

Most of the annuli appear double, when the leech is at rest. To ascertain the whole number of annuli, it is necessary to count from the dorsal side, and to begin with the ring bearing the first pair of eyes. There are sometimes one or more faint indications of rings in front of this point, but they cannot be safely counted.

Buccal Annuli—the 5th and the 6th, the ventral halves of which are united.

Post-buccal Annuli—the 7th and the 8th, also united below.

Genital Apertures.—The male orifice lies in the posterior edge of the 30th annulus (24th counting from the buccals on the ventral side), often appearing in hardened specimens, to lie between the 30th and the 31st. The vulva lies five rings behind the male orifice, in the posterior edge of the 35th annulus, in hardened specimens apparently between this and the 36th. In specimens obtained from Aomori, both orifices were exactly between the above-named annuli.

The male orifice is located between the 2nd and 3rd annuli of the 10th somite; the female orifice, between corresponding annuli of the 11th somite.

Clitellum embraces the 9th, 10th, and 11th somites.

Anus in the 102nd, or last annulus.

Ocelli, five pairs. The first three pairs form a semicircle on the first three annuli, each annulus bearing a single pair of eyes; the fourth pair is placed on the 5th annulus, or first

buccal; the fifth pair on the 8th annulus, or second post-buccal (fig. 10).

Œsophagus has six folds.

Maxilla three, armed with from sixty to seventy straight, conical denticles.

Nephridia, seventeen pairs. The first pair is located in the 6th somite, the seventeenth pair in the 22nd somite. The nephridial pores are placed on the ventral side in the posterior edge of the last annulus of each somite. These pores then occur in the following rings: the 13th, 18th, 23rd, 28th, 33rd, 38th, 43rd, 48th, 53rd, 58th, 63rd, 68th, 73rd, 78th, 83rd, 88th, and 93rd. There are thus four pairs of nephridia before the male orifice.

The vesicles are oval sacs, measuring in sections of hardened specimens 0·8 mm. by 0·6 mm., and bridging only two rings. The three pairs of vesicles situated in the clitellum do not appear to differ in any respect from the rest.

Segmental Papillæ. — Beginning with the 5th ring, which bears the fourth pair of eyes, we find twenty-two papillate rings, in the following order,—5th, 8th, 11th, 14th, 19th, 24th, 29th, 34th, 39th, 44th, 49th, 54th, 59th, 64th, 69th, 74th, 79th, 84th, 89th, 94th, 97th, and 99th. Traces of these papillæ are seen also on the 101st. The dorsal side of each of these annuli, if we except the 5th and the 101st, bears six minute papillæ, a median pair and two lateral pairs. Possibly there may be a marginal papilla on each side, in addition to these, but none was recognised. As these papillæ are regularly placed on every fifth ring, except near the ends, where the intervals are reduced, they may be said to form six longitudinal rows (Pl. XVIII, fig. 10). These papillæ are quite conspicuous in fig. 18, as in this exceptionally coloured specimen each is encircled by a ring of dark brown—a little darker than the pigment of the brown stripes. The area or spot thus encircled is dusky yellow, and shows at the centre a minute round dot that is entirely free from pigment. The papillæ are minute and project only slightly, and the circular areas which they occupy appear as mere pigment spots to the naked eye.

Anteriorly as well as posteriorly these pigment circles become obscure. They are just distinguishable on the 5th and 8th rings, a little more distinct on the 11th, and well defined from the 14th to the 94th. They are small on the 97th, faintly marked on the 99th, and reduced to the merest rudiments on the 101st.

The median spots are arranged along each side the median yellow stripe, projecting somewhat into it and thus causing it to appear contracted or narrowed at regular intervals. The lateral spots are placed along the middle of the narrow dark brown stripes on either side (figs. 10, 18, and 21). The inner rows of lateral spots are directly in line with the eyes, and hence the most anterior of these spots are found on the 11th ring.

Six rows of segmental papillæ occur also on the ventral side, and these are arranged as seen in fig. 13. Here we find two median rows, two lateral, and two marginal. The marginal rows are in the marginal yellow stripe, very near the edge; the lateral rows are a little farther removed from the median ventral line than the nephridial pores, and are about equidistant from the median and marginal rows. These papillæ are considerably smaller than those of the dorsal side, and on this account were for some time entirely overlooked.

Colour.—This species exhibits great variability in colour and markings—so great that when the extremes are placed before us we find it easy to distinguish at least twenty or thirty different patterns. A careful study of these forms has led me to the conclusion that they all belong to the same species, and that their differences are purely individual, and not such as to authorise even the distinction of "varieties." All the figures seen in Pl. XVIII, except 15 and 16, which represent individuals from Aomori, were drawn from living specimens obtained from streams and ponds in and around Tokio. Fig. 19 represents the more common colour and marking, and may be regarded as a typical example of the species; while figs. 14 and 18 show two very wide departures in respect to colour.

The ground colour of the more typical specimens is brownish olive above and pale or yellowish olive below. The typical markings of the dorsal surface are five longitudinal yellow stripes, bordered on each side with very dark brown or black, and usually interrupted (figs. 17 and 19) or blurred (fig. 11) on the first or papillate ring of each somite. The median stripe, which is the broadest and brightest, widens a little on the cephalic lobe between the eyes, and usually terminates behind in a more or less semicircular patch on the acetabulum. The only markings below are two irregular, often nearly obsolete, dark brown streaks bordering the yellow margins (figs. 13 and 20).

The figures of Pl. XVIII have been selected with a view to showing both the degree and the method of variation in colour-markings. The differences in this respect between figs. 18 and 19 are so extreme that it seems at first sight difficult to reconcile them with the fact that the figures represent specifically identical individuals. The specimen represented in fig. 18 was examined closely and found to agree in every particular, except colour, with the common Medicinal Leech of Japan. It was found in a stream that flows alongside the shallow lake known in Tokio as Shinobazu no Ike, where the common Leech is extremely abundant. Among hundreds of Leeches collected at many different times from the same locality this was a solitary example in colour, and hence must be regarded as an individual colour-variety.

An interesting question now arises. Are these colour-varieties mere variations or modifications of what I have described as typical? or are they so many different patterns having no sort of relationship with one another? A closer inspection of the figures shows that the first of these questions must be answered in the affirmative. In fig. 18 the olive shades have almost wholly disappeared, leaving the ground-colour a dull dingy yellow, marked by six irregular dark stripes. If the yellow ground between these stripes be regarded as corresponding to the yellow stripes of most specimens, as plainly indicated by the position of the segmental

papillæ, then we may say that the dark brown stripes correspond to the dark borders of the yellow stripes. But in the typical specimen there are five yellow stripes and twice as many dark borders; how then can these ten borders be represented by six dark stripes? Fig. 10 is an enlarged pencil sketch showing accurately the distribution of the dark pigment of fig. 18. From this figure it will be seen that each of the dark stripes appears to be composed of two parallel halves that have imperfectly blended, leaving here and there evidences of their duplicity. This is especially manifest in the two broader median stripes, and but little less so in the external lateral stripes. These six stripes may then be said to represent twelve dark borders, of which ten ordinarily accompany the five yellow stripes, and two form the inner borders of the yellow margins.

Now, there are three ways in which the dark borders could be made to unite in pairs. First, the widening of the yellow stripes would bring together the six pairs of adjacent borders; second, the widening of the borders themselves, allowing that the yellow stripes persist, would accomplish the same result; third, the obliteration of the yellow stripes would bring together the two borders of each stripe. These three cases are all more or less perfectly represented in the figures of this plate.

In fig. 18 it is the widening of the yellow stripes and the yellow margins that accounts for the arrangement of the dark pigment. That the dusky yellow area enclosed between the two median dark stripes corresponds to the median yellow stripe of the typically coloured specimen, is made sufficiently evident both by its position and by the manner in which it terminates on the cephalic lobe (fig. 18), and on the acetabulum (fig. 10). If this correspondence be conceded, a parallel correspondence must also be claimed for the two lateral dusky yellow areas of each side.

In fig. 11, which represents a portion of fig. 12 magnified four diameters, we have an illustration of the second case, in which there are six dark brown stripes formed, not by the

widening of the yellow stripes, but by replacing the olive-ground colour between these stripes with a brownish black almost as dark as the dusky borders of the stripes. This darkening of the ground-colour is equivalent to widening the six pairs of adjacent dark borders until each pair blends into a single dark stripe. The blending is not quite complete throughout, so that there still remains unmistakable evidence of the double origin of the dark stripes, especially in the inner of the two lateral ones of each side. It will be noticed by comparing figs. 11 and 18 that the segmental papillæ hold the same position relative to the stripes in both cases. A similar case of darkening the ground-colour is seen in figs. 15 *d*, and 20.

An illustration of the third case, in which the two dark borders of the yellow stripe are brought together by the obliteration of the stripe, may be seen in fig. 16 *d*, which represents a portion of a Leech from Aomori; and again in fig. 17, a specimen from Tokio. In the Aomori specimen the external lateral yellow stripes have been completely effaced, the dark borders of each uniting to form a narrow dark stripe on each side. In the two inner lateral stripes, small remnants of the yellow are still to be seen at intervals. The median stripe is a bright lemon yellow, well preserved throughout, and accompanied by the usual dark borders. Both specimens from Aomori show only mere shadows of the dark stripes bounding the yellow margins on the ventral side (figs. 15 and 16). In the specimen from Tokio, it is the two inner lateral yellow stripes that have been wholly effaced, while the external ones are preserved only at intervals. The median yellow stripe is here interrupted on the papillate rings; it broadens as usual on the cephalic lobe, but does not extend to the acetabulum. Here the dark borders of the median stripe are very distinct.

In fig. 14 is represented a specimen in which the yellow stripes and their borders and even the ground-colour have faded. The stripes are barely indicated, and, contrary to the rule, the dorsal side is lighter than the ventral.

The yellow stripes are rarely evenly continuous as in fig. 15,

being generally constricted on the papillate rings (fig. 11) or entirely interrupted (figs. 17, 19).

Only a few examples of this Leech were found in Yezo (officially called Hokkaido), and these agreed so perfectly with those found about Tokio that I am inclined to believe that this island is indebted to the main island for its scanty stock of Medicinal Leeches. In one specimen obtained in Hakodaté, I noticed that the dark borders of the median stripe broadened conspicuously on the middle rings of each somite, which is a feature not infrequent in the Leeches of Aomori and Tokio.

Habitat.—This Leech is very abundant in the ditches and slow streams in the low plains of Tokio, and especially so in the open sewers of this and other cities of the main island. I have occasionally found it in shallow pools in rice fields.

Habits.—Its habits and mode of life are precisely the same as those of the Medicinal Leech of Europe.

Internal Organization.—The structure and relations of the internal organs are almost identical with those in H. medicinalis. There is the same number of ganglia, testes, nephridia, and cæcal appendages of the alimentary tract, and all hold precisely the same relative positions.

The azygous terminal portions of the reproductive organs open beneath the nerve-cords, between the sixth and seventh and between the seventh and eight pairs of ganglia, counting the sub-œsophageal ganglia as the first. The intromittent organ lies on the right, the vagina on the left, of the nerve-cord. The ovaries (Pl. XXI, fig. 65) are small pyriform sacs of about the same size, and occupying the same position with relation to the nerve-cord and the ganglia as the testes. They lie nearly in the same vertical transverse plane with the vaginal orifice, just in front of the vagina. As in H. medicinalis,[1] the oviduct leading from the right ovary passes under the nerve-cord, uniting with the left oviduct at the level of the anterior end of the vagina. The common oviduct (*od. c.*) (oviductus communis) is somewhat tortuous, and its anterior half is enveloped by a mass of unicellular glands, the

[1] Rolleston, 'Forms of Animal Life,' p. 221.

glandulæ albuminiferæ (*gl. alb.*), first made known by Leuckart.[1] This duct lies loosely on the vagina (*v*) and bends into the posterior end of the latter. The vagina consists of a fusiform saccular portion and a narrow tubular portion leading to the external orifice. The saccular portion has about the length of one somite; but it lies opposite the eighth pair of ganglia, so that one half is in the 11th, the other in the 12th somite. The anterior tubular portion appears to be longer than in H. medicinalis.

Remarks and General Considerations.

Name.—I have found no mention of this Leech anywhere except in a few quasi-scientific books of Japanese origin. The more common native name is Hiru, which has, so far as I can learn, only an accidental resemblance to the Latin Hirudo. According to the best information I could obtain, this name has always been in common use among the Japanese; and it is quite certain that it is not a shortened form of Hirudo, as the latter could only have been introduced in comparatively recent times. The same word also signifies garlic, noon, daytime. A similar name, Hiiru, is applied to the mouth of a silkworm.

According to J. C. Hepburn, the name Suitetsu (from sui, to suck, and ketsu, blood) is also applied to the Leech. Neither the Corean name Kōmōri, nor the Chinese Chitsu gives any clue to the origin of the word Hiru.

A Japanese writer, Tanikawa ('Wakunshiori,' vol. xxv, 1830), attempts to explain the matter, by saying that the Leech lives in the mud, hiji, and is therefore called Hiru.

Use.—This is the only Leech used by the Japanese for medicinal purposes. According to an older author, Terashima ('Wakansansaidsuye,' vol. lii, 1713), the Japanese have not only employed the Leech in the common way, externally, but also as an internal medicine. As an example, the writer says that the Leeches are dried and reduced to fine powder, of which about

[1] 'Die menschlichen Parasiten,' i, p. 679, 1863.

eight grains are taken with saké (rice-wine) to cure "sessho totsu" (which was interpreted to me as pains resulting from broken limbs). If the pain continues, a second dose is taken, which soldom fails to bring relief!

In external use the Leech is applied by the aid of a bamboo tube.[1]

The Diagnostic Value of the Annuli.—In the past descriptions of Leeches, there has been a growing recognition of the fact, that the number, character, and metameric combination of the annuli furnish important marks for the determination and comparison of species. Gratiolet and Grube are the only authors, however, who have shown any very clear appreciation of this point. The general neglect in this respect is doubtless attributable to the difficulty in counting and describing accurately the annuli on the two ends of the body, as well as to a lack of appreciation of their importance for systematic purposes. The result is that, up to the present moment not a single description of any Medicinal Leech has been given with sufficient completeness for a close and full comparison of even its more important external characters with those of other species. More than this, it would be impossible, from the innumerable monographs, memoirs, and stray papers on the Medicinal Leech, to patch up a description that would fully meet the obvious requirements for a critical comparison of any two species. I am well aware of the import of these statements, for my experience has given me a keen sense of their meaning. So far as the matter in hand is concerned, I venture to say that by far the greater number of the species-diagnoses that have been showered upon us from time to time, have been so superficially and slovenly done, that it would puzzle the perpetrators to identify the species they profess to have described. I wish here to insist on the importance of a thorough study of the annuli of the Leech, particularly those of the abbreviated terminal somites, as a means of making clear the precise position and relation of the parts

[1] For these references to Japanese literature, I am indebted to Mr. Tanada, who was my assistant in the zoological laboratory at Tokio.

which assist in the determination of species. I have satisfied myself that not only the number and position of the rings, but the relative size and general appearance of each ring even to very minute details,[1] are accurately reproduced in every normal individual of a species. The obscurity that is supposed to exist in regard to the precise number of rings which enter into the composition of the cephalic lobe or the hind end of the body, affords no excuse for the meagre descriptions usually given of these regions, but furnishes rather an argument for describing them with the utmost care and detail. As to the difficulties in the way of counting, these are scarcely worth mentioning in the various species of Hirudo, or of the allied genera, Aulostoma, Hæmopis, Macrobdella, &c. It is only necessary to adopt some method of counting that can be safely followed in all these genera. What my own method is, I have made clear in the foregoing descriptions; and it now remains only to show its advantages over those proposed by other writers. As before pointed out when comparing the Land Leech with the Medicinal Leech of Japan, it will not do to follow Moquin-Tandon, Diesing, and others in counting from the ventral side, for some of the more important rings are not seen from this side; and the dorsal aspect of some rings, particularly the buccals and post-buccals, differ very much from the ventral. Besides, the abbreviated somites can only be clearly described by an accurate study of the dorsal side; and it is here that the sense-organs attain their highest development, and the colour-markings their more important diagnostic distinctions. The total number of annuli, the position of the sexual orifices, the nephridial pores, and the segmental papillæ, must therefore all be determined by reference to the dorsal side, the differences between this side and the ventral being noted wherever necessary.

A still more objectionable method is that of counting the annuli from the anterior end, but from two different points, one on the dorsal the other on the ventral side. Thus the organs of the two sides, being located with reference to two

[1] Colour alone excepted.

different starting-points, are thrown out of relation, and confusion is the consequence. The confusion consists in this, that the dorsal and ventral halves of the same ring bear two different numbers. In the case of Macrobdella decora, for instance, the dorsal half of the buccal ring, according to Verrill, is counted as the 6th, five rings preceding it; while the ventral half is called the 1st, starting from the mouth. In the same way the male orifice is said to lie in the 27th ring behind the mouth: but what is the number of this ring on the dorsal side? It is certainly a very simple matter to add five, the number of rings supposed to belong to the cephalic lobe, to twenty-seven; but this alone would not give us the number on the dorsal side in any Leech which, like the Medicinal Leeches of Europe, China, and Japan, has four rings (two buccals and two post-buccals) represented by two on the ventral side. The simplest method, and the one least liable to confusion, seems therefore to be that of numbering the rings from one fixed point on the dorsal side. Each ring then has a definite number and precise relations.

Gratiolet was the first to emphasize the importance of a well-defined starting-point in counting, as a means of determining with precision the position of the genital pores. Under the persuasion that no such point could be found on the dorsal side which would be convenient in use, he recommended the posterior pair of nephridial pores as the most satisfactory point of departure, reckoning from this point forward. The considerations which led him to adopt this unconventional and somewhat awkward method, may be seen from the following:

"La chose importante dans cette recherche serait de partir d'un point fixe et nettement défini. Or, la plus grande incertitude régnant sur le nombre des anneaux aux deux extrémités de l'animal, il faudrait en conséquence pouvoir les négliger. En y réfléchissant un peu, le problème ne paraîtra pas absolument insoluble. Quand on étale une Sangsue morte ou vivante, et qu'on la fait glisser sur sa face dorsale appliquée sur la convexité du doigt indicateur, on aperçoit, d'espace en espace, deux petites gouttelettes de liquide symétriquement accumulées sur le bord postérieur de certaines anneaux. Ces

gouttelettes s'échappent de petits orifices qui conduisent par un canal oblique et fort étroit, à certaines vésicules intérieures, dont nous parlerons dans un instant. Ces orifices, ainsi que nous venons de le dire, sont disposés en paires symétriques, et ces paires sont séparées les unes des autres par des intervalle- qui, à la partie postérieure du corps, comprennent régulières ment cinq anneaux. Or elles sont au nombre de dix-sept, et par conséquent, si le nombre des anneaux compris dans ces intervalles est fixe entre la première et la dernière, il y a nécessairement quatre-vingts anneaux. Malheureusement ce chiffre n'est par exact; en effet, le nombre des anneaux varie à l'extrémité antérieure de la série, où d'ailleurs les orifices sont très difficiles à discerner. Le seul point fixe, ou du moins le plus commode, se trouve dans la paire postérieure d'orifices qui est tonjours distinct et facilement apparente . . . .

"Le nombre des anneaux intermédiaires décroît vers l'extrémité antérieure de la série; c'est ainsi que le quinzième intervalle, compté d'arrière en avant, n'a que quatre anneaux, et le seizième trois seulement; dès lors, le nombre total des anneaux, compris entre les deux paires extrêmes d'orifices, n'est pas de quatre vingts anneaux, comme on aurait pu l'admettre à priori, mais de soixante-dix-sept (l. c., p. 10, 11).

The objections to counting from the ring bearing the last pair of nephridial pores are:

1. It is an unnatural and confessedly a forced method.

2. It does not answer all the ends that may be reached by beginning with the first pair of eyes.

3. It is an attempt to evade the difficulties involved in the obscurity of the rings at the two extremities.

4. It is necessarily limited in its application to those few genera in which the posterior pair of nephridial pores are sufficiently distinct to be easily recognised.

The examination of the abbreviated somites has already revealed to us a natural, convenient, and precisely defined starting-point for counting in Hæmadipsa and Hirudo. For reasons before given, it is certain that the first three pairs of eyes in Hirudo mark three successive rings. Beginning

then with the first pair of eyes, we find the fourth and fifth on the fifth and eighth rings respectively. Now this simple arrangement of the eyes which is only slightly modified in Hæmadipsa, holds good not only for Hirudo, but for Hæmopis, Aulostoma, Macrobdella, and all the more closely related genera. From the fifth pair of eyes onward, the counting is rendered more easy by the size of the rings, as well as by the metameric arrangement of the colour-markings and the segmental papillæ. It is certainly very desirable that the various species of the above-named genera should be described on a common plan. It seems to me that for simplicity and clearness there is no better method than the one here recommended. It is quite certain that no clearly marked ring exists anterior to the first pair of eyes that would serve the purpose we have in view. There are here, to be sure, in some species, obscure traces of what, in the opinion of some authors, might be regarded as one or two rings. While it is important to take note of all such evidences of rings, it is certainly advisable, for the sake of uniformity, to discard them in counting.

Abbreviated Somites.—The comparison of Hæmadipsa with Hirudo nipponia has shown that we cannot afford either to ignore the rings composing the two ends of the body, nor to pass them over with such imperfect descriptions as are usually accorded to them. That the terminal somites are more or less abbreviated or shortened, by suppression of rings, is a fact recognised by all recent writers; but no one has hitherto thought it necessary to give more than a very superficial account of them. Gratiolet's method of counting was adopted with a view to avoiding a close study of these somites; and, certainly, it is admirably adapted to this end. Fortunately, the position of the five pairs of eyes has been sufficiently well-defined to enable us to understand the composition of the first four somites in Hirudo and cognate genera; beyond this, our information is too meagre and indirect to settle either the number or the composition of the abbreviated somites.

Gratiolet finds one hundred and two annuli in H. medicinalis, as will be seen from the following figures:

From tip of head to first pair of nephridial pores	10
Between first and last pair of nephridial pores	77
Between last pair of pores and anus	9
Acetabulum	6
Total number	102

Following the same order in the case of H. nipponia omitting the acetabulum, we have:

From tip of head to first pair of pores	13
Between first and last pair of pores	80
Between last pair of pores and anus	8
Between anus and acetabulum	1
Total number	102

The most important difference here is found in the number of rings that separate the two extreme pairs of nephridial pores. In the Japanese Leech (fig. 10), there are sixteen unabridged somites between these two points, the 7th to the 22nd inclusive. In the European Leech, according to the statements cited from Gratiolet, the 7th somite is composed of three rings, and the 8th of four rings; the remaining fourteen containing each five rings. Thus, if we accept Gratiolet's statements, we must allow that H. medicinalis has eight abbreviated somites at the anterior end, while H. nipponia has only six abbreviated at this end. Now such a difference is, as will be shown in the sequel, quite irreconcilable with the opinion that the two species belong to the same genus. In order to remove all doubts as to the propriety of placing the Japanese Leech in the genus Hirudo, I have examined a considerable number of Medicinal Leeches from different parts of Europe and Asia, as well as Aulostoma, Hæmopis, and Macrobdella Verrill. This examination has brought to light some facts concerning the composition of the body of the Leech, which has hitherto escaped notice, facts which will serve as a basis for comparative systematic studies,

and at the same time as a most important guide to the genealogical relationship of the various species and genera.

The Genus Hirudo.—Every Hirudo has twenty-six somites, counting from the first pair of eyes to the acetabulum: ten of these—the first six and the last four—are abbreviated by the suppression of from two to four rings in each; and sixteen, lying between the first and the last pair of nephridial pores, have each five rings. The six anterior somites include thirteen rings,—the 1st and 2nd being represented each by a single ring, the 3rd by two rings, and the 4th, 5th, and 6th, each by three rings. The four posterior somites embrace nine rings (94—102), the 23rd somite including three rings, and the 24th, 25th, and 26th, each two rings.

The first ring of each somite is marked, anteriorly, by a pair of eyes; and, from the 11th ring onward, by the segmental papillæ, of which there are normally from six to eight on the dorsal half of the ring and six on the ventral half.

The serial homology of the segmental papillæ and the eyes is apparent from their arrangement; for the first pair of eyes replace a pair of median papillæ; and the remaining four pairs of eyes replace as many pairs of the inner lateral papillæ.

The eye-bearing rings are the 1st, 2nd, 3rd, 5th, and 8th.

The buccals are the 5th and 6th, which are united on the ventral side. The post-buccals are the 7th and 8th, also united ventrally.

The first pair of nephridial pores is situated in the 13th ring; and the last (17th) pair in the 93rd ring.

The male orifice lies between the 30th and the 31st ring, the second and third of the 10th somite. The female orifice is five rings behind the male, and

thus holds a similar position in the 11th somite, between the 38th and the 36th ring.

The anus lies in the 102nd ring, or between this and the preceding one.

The other characters of this genus, such as the maxillæ, denticles, alimentary tract, reproductive organs, nephridia, &c., are too well known to require repetition here.

I shall presently bring abundant evidence to show that the above characters are typical of Hirudo; and that any well-marked departure from this type, in the total number of somites, in the number or composition of the abbreviated somites, with perhaps the exception of the 26th somite, in the number or position of the eyes, nephridial pores, sexual orifices, &c., cannot be consistently admitted for any species included in this genus. If this conclusion be correct, some names will certainly have to be expunged from our lists of genera; but no objection on this ground can outweigh the advantages of a clearly defined and convenient standard of comparison. When we remember that naturalists began by referring almost every Leech, even Clepsine, to the genus Hirudo; and that some of our more recent authorities have gone to the other extreme, of setting up new genera on distinctions of doubtful significance, it becomes evident that a genus should stand for something more than a name coupled with a few observations that leave us in the lurch whenever we seek to know its precise limits and relations to other genera.

A close comparison of the Japanese Medicinal Leech with those imported from Sweden, and with those which I collected myself in Saigon, Singapore, Ceylon, and Naples (Sebeto River), enables me to say that all the characters above named are common to these widely separated and distinctly marked species. It is more than probable, therefore, that Gratiolet was in error as to the number of rings in the 7th and 8th somites.

Aulostoma and Hæmopis.—I have been surprised to find such a close agreement among the different species of Hirudo, in regard to the number and character of the rings as

well as the number and composition of the abbreviated somites; and still more so, to find these characters repeated with all the more important details of number and position in both Hæmopis, and Aulostoma. This certainly indicates a close relationship between the three genera. Aulostoma is, however, a well-founded genus, distinguished from Hirudo by its habits, mode of life, form of its alimentary canal, character of its teeth, and the position of the male orifice, which is in the middle of the 31st ring, instead of between this and the 30th. In the case of Hæmopis, the distinctions are so few and unimportant that it is difficult, if not impossible, to justify a separation from Hirudo. Hæmopis is a complete copy of Hirudo in all the particulars before named, and its highest claim to generic rank is based on the small number of its denticles. In view of the great variability in the number of the denticles, not only among different species of one and the same genus but also among individuals of the same species, and even in the different jaws of the same individual, this distinction hardly deserves generic rank. The other distinctions on which this genus rests, whether considered singly or collectively, are even less satisfactory as generic characters. Leuckart[1] long ago declined to recognise Hæmopis as a distinct genus. After defining the genus Hirudo, he remarks:—"Thus characterised, the genus Hirudo embraces not only the larger number of species hitherto referred to it—with the exception, e.g. of H. lateralis, Say—but also the genus Hæmopis, the separation of which we must regard as unsound so long as the usual distinctions ('body less flat, less deeply annulated at the margin, in contraction less olive shaped, denticles less numerous') are not replaced by others of a more positive value."

Hirudo and Hæmopis both require the same food, and obtain it from the same sources and by the same means, with the single difference, that Hæmopis, which is provided with denticles too short and dull to make an incision in the epidermis, is restricted in its attacks to epithelial surfaces which

[1] Leuckart, 'Die menschlichen Parasiten,' i, p. 716, 1863.

are easily sawn asunder, such as are found in the mouth and the nostrils.

The genus Hæmopis appears thus to rest on an insufficient basis; and, as its rejection will be more consistent with our present nomenclature than its retention, I venture to propose its reabsorption in the genus Hirudo.

Does then the number of denticles furnish any guide in the determination of genera? Is there any point in the reduction of the number of denticles which can be taken as a limit to the genus Hirudo? All will agree that there is at least one such point; and I think a little reflection will show that there is only one. So long as the denticles are sufficiently numerous and well formed to enable the Leech to live by sucking blood, it is plain that the reduction has not reached a point at which the formation of a new genus becomes imperative. When, however, the number and efficiency of the denticles have been reduced to such an extent that the Leech becomes incapable of drawing blood, and is thus compelled to accept a different kind of food and to adopt new methods of obtaining it, it is obvious that the boundary line between two very distinct courses of life has been passed. The degeneration of the denticles has been carried to a point that necessitates a complete revolution in habits, and a whole train of correlated morphological changes sweep in. Such has been the history of Aulostoma. The climacteric limit in the reduction of the number of denticles lies between Aulostoma and Hæmopis, and this limit is the only one which, in this direction, can be found for the genus Hirudo. Between the maximum and minimum number of denticles compatible with the life of Hirudo, I can see no limit to variation that is entitled to generic rank. Any attempt to establish a limit to the genus inside of these extremes, must be pronounced irrational, since it makes it impossible to draw any line between specific and generic distinctions. The futility as well as the absurdity of such an attempt has been shown in the use that has been made of the genus Hæmopis. Various Land Leeches have been referred to Hæmopis, not on account of any real generic affinity, but simply

because they were said to have fewer teeth than are usually found in Hirudo medicinalis. It is evident too that certain aquatic Leeches, although much further removed from Hæmopis than this genus is from Hirudo, have, nevertheless, been associated with the former on the same insufficient ground. A similar blunder has been made in the attempt to make the entire absence of denticles a basis of generic association. The discovery of toothless Leeches in different parts of the earth, which have evidently descended from different species of denticulated Leeches, shows how unreliable and worthless genera are when founded on such characters. But if the entire absence of denticles is no certain indication of generic affinity, how much less certain is a difference in number only. I have satisfied myself that two Leeches belonging to two distinct genera may often agree more nearly in the number of denticles than two species of the same genus. Numerous instances of this kind are at hand, but one or two will be sufficient here. No one will deny that Macrobdella, Verrill, and Hirudo are quite distinct genera. Now Leidy[1] has described a species of Macrobdella with fifty-five teeth; and Schmarda[2] states that Hirudo quinquestriata (from Australia) has from forty-eight to fifty teeth. It is also stated by Schmarda that H. multistriata (Ceylon) has about one hundred teeth.

Again, Macrobdella floridana Verrill, has only "about twenty acute teeth,"[3] thirty less than Macrobdella, Leidy. In M. sestertia (n.sp.) I have found one jaw furnished with thirty-nine, the second with forty-three, and the third with forty-six teeth. Schmarda found only thirty teeth in Hæmopis ceylonica, which is a Land Leech belonging to Hæmadipsa—a genus sufficiently distinct from Macrobdella.

If we are to avoid increasing the number of genera until they equal or nearly equal the number of species, it is evident

[1] Leidy, 'Proc. Phil. Acad. Nat. Sci.,' p. 230, 1868.

[2] Schmarda, 'Neue wirbellose Thiere,' i, 2nd part, p. 2, 1861.

[3] Verrill, 'Synopsis of the North American Fresh-water Leeches," p. 669, 1874.

that we must find some better basis for distinguishing genera than has yet been offered in the case of Hæmopis.

The Somites as a basis of Classification.

I shall conclude my remarks on the somites as a basis for distinguishing genera, by a comparison of genera from different countries. That such an important basis of classification has thus far been completely ignored, is due to the fact that the segmental papillæ have hitherto attracted very little attention. It is the metameric arrangement of these peculiar sense-organs, which I regard as incipient eyes, which has revealed to me the degree of abbreviation that has taken place in the terminal somites, and thus led to the discovery of characters which serve to fix precise limits to genera, and to determine their phylogenetic relationship. The following descriptions, added to those already given of Hæmadipsa and Hirudo nipponia, will make clear the facts on which some of the foregoing conclusions rest.

1. Hirudo medicinalis (Sweden). In order to define the position of the segmental papillæ, the colour markings must be briefly noticed. In the specimen examined the dorsal surface was marked by six brownish-yellow stripes. The two median stripes were about one third of the width of the body distant from each other, and thus divided the dorsal surface into a median and two lateral areas. The lateral stripe of each side lay near the median stripe, separated from it by considerably less than half the width of the lateral area. On every fifth ring (last of each somite) the lateral stripe inclosed a more or less triangular black spot, the more elongated angle of which pointed forward. Similar spots, but much smaller, were also seen in the median stripes on the same rings. The two latero-marginal stripes were very narrow and were separated from the yellow margins by a narrow black stripe. This black stripe widened on the last ring of each somite, in the direction of the middle dorsal line, thus causing the latero-marginal stripe to form a curve at these points in the same direction. The median and lateral stripes coalesced on each side near the

hind end of the body, and were then continued as one stripe to the edge of the acetabulum. The same stripes coalesced also anteriorly.

The ground-colour of the dorsal surface was a dull olivaceous green; the ventral sarface was pea green thickly flecked with black. The yellow margins were bounded on the ventral side by a broad black stripe, the inner edge of which was quite uneven.

The dorsal half of the papillate rings bears eight segmental papillæ; the ventral half six. On the dorsal side (Pl. XX, figs. 47, 49) we see two median rows of papillæ (*m.*), located on the following annuli—2, 3, 5, 8, 11, 14, 19, 24, 29, 34, 39, 44, 49, 54, 59, 64, 69, 74, 79, 84, 89, 94, 97, 99, 101; two inner lateral rows (*il.*), beginning on the eleventh annulus, and following the line of the lateral stripes to the posterior end of the body; two outer lateral rows (*ol.*), near the outer edge of the lateral areas of colour, beginning as far forward as the fifth annulus and traceable to the 101st annulus; and two marginal rows (*mg.*), located in the narrow latero-marginal yellow stripe. On the ventral side (fig. 48) we find two marginal rows (*mg.*), located in the inner edge of the yellow margins of the body; two lateral rows (*l.*), just inside the black stripes; and two median rows (*m.*), separated from each other by a little less than one third the width of the body.

The median rows of the dorsal side exhibit serial relationship with the first pair of eyes; while the inner lateral rows, which are larger and more conspicuous than the others, show a similar relationship with the remaining pairs of eyes.

Counting from the first pair of eyes to the anus, there are twenty-six somites, of which six at the anterior and four at the posterior end are abbreviated, leaving sixteen full somites between the first and last pair of nephridial pores. The total number of annuli is 101, of which thirteen belong to the first six somites, eighty to the sixteen full somites, and eight to the last four somites. The 1st and 2nd somites are each represented by a single ring; the 3rd by two rings; the

4th, 5th, and 6th, each by three rings; the 23rd somite includes three rings; the 24th and 25th each two rings; and the 26th one ring, with an occasional rudiment of a second (the 102nd).

The 5th and 6th rings, designated as the buccal rings, completely coalesce on the ventral side; and the same is true of the two post-buccals (7th and 8th). This apparent coalescence really means the suppression of the ventral half of the non-papillate ring.

The nephridial pores are placed in the posterior edge of the last ring of the somite; the first pair (1st p.) in the 13th ring, and the seventeenth pair in the 93rd ring.

The male orifice lies two rings behind the fourth pair of pores, between the 30th and the 31st ring; the female orifice lies five rings behind the male, between the 35th and the 36th ring.

The anus lies behind the 101st ring. The post-anal ring (102nd) is at best only rudimentary, and can only doubtfully be claimed as belonging to the body.

In the Medicinal Leech found in Sebeto River (Naples), we have only a few differences to note. The two buccals are faintly demarcated on the ventral side, while the post-buccals are fully united. The total number of rings is 102, and the anus lies in the 102nd ring, nearly dividing it (fig. 50).

Except in colour-marking and size, the European Hirudo agrees almost perfectly with H. nipponia.

2. Aulostoma of Leipsic and Naples. Whether the Aulostoma of Leipsic is specifically distinct from that of Naples or not, is a question that I am not prepared to answer decisively; and I will not therefore prejudge the case by giving them different names. My examinations have been made mainly for the purpose of ascertaining how far the somites correspond to those of Hirudo.

The total number of rings between the first pair of eyes and the anus is 100, one less than in Hirudo; but this difference turns out to be of subordinate importance. As shown in fig. 52, the anal aperture is very large, completely dividing two

narrow rudimentary rings (101 and 102), and even encroaching somewhat upon a third (100). This figure represents a specimen obtained at Leipsic. In specimens from Naples, the last two rings (99 and 100) show signs of duplicity at their margins; and in one or two cases, it is perfectly evident that both of these rings are double, the 99th corresponding to the 99th and 100th in Hirudo, and the 100th to the 101st and 102nd. Allowing that such a correspondence actually exists, we should expect to find segmental papillæ on both of these rings. They are always present on the 99th ring, and in a few cases they are quite distinct on the 100th ring. It is safe to conclude therefore that Aulostoma has the same number of rings as Hirudo, with the difference that in the former the 100th and the 102nd, which are non-papillates, are less distinct than in the latter. In the Leipsic specimens (fig. 52) the 101st and 102nd rings are very distinctly indicated, but not in the same way. It is not improbable that the difference here pointed out may have the value of a specific distinction.

The 23rd somite has three rings, but it is noticeable that two of these rings (95th and 96th) are much thicker than the preceding or the following rings, showing that the abbreviation of this somite has not been carried quite so far in Aulostoma as in Hirudo. The abbreviation of the 25th and 26th somites, on the contrary, is somewhat more extreme than in Hirudo. With respect to the anterior abbreviated somites, I am unable to point out any differences between the two genera.

The nephridial pores hold the same positions and relations in both cases, and there is only a difference of half a ring in the position of the male orifice, which generally occupies the middle of the 31st ring,[1] instead of lying between the 30th and the 31st.

The number and arrangement of the segmental papillæ are the same as in Hirudo; but the median dorsal and all the ventral papillæ are less strongly developed. In some specimens the papillæ are quite distinct on the acetabulum (fig. 52).

The denticles are from eleven to fifteen in number, but vary

[1] I have sometimes found this orifice in the anterior edge of the 31st ring, very near the line dividing this from the preceding ring.

considerably in different individuals in respect to the degree of development attained.

3. Hirudinaria javanica (Hirudo javanica Wahlberg).—Dr. C. Ph. Sluiter, of Batavia, has been kind enough to send me some very excellently preserved specimens of this interesting Leech, together with drawings and full descriptions of the colour-markings. I have given the alcoholic specimens a thorough examination, and am able to add some facts to those communicated by Dr. Sluiter.

This Leech resembles, in some respects, Hirudo maculosa, Grube,[1] but differs from it and from all other Medicinal Leeches known to me in two very striking peculiarities, namely, the separation of the sexual pores by seven instead of five rings, and the enormous size of its acetabulum, which reaches forward to the level of the last pair of nephridial pores. The first-named distinction alone appears to me quite sufficient to justify its separation from Hirudo, and it is on this ground that I propose to give it the generic name Hirudinaria.

This genus agrees with Hirudo in the number and composition of its somites, and in having precisely 101 rings between the first pair of eyes and the anus. The dividing line between the buccal rings (5th and 6th) extends to the ventral side, but vanishes before reaching the median line of this side. The post-buccal rings are somewhat more perfectly united on the ventral side. The male orifice lies between the 30th and 31st ring, the female orifice between the 37th and 38th ring. The 102nd ring, which forms a sort of neutral zone between the body and the posterior sucker, is broken into two lateral halves by the anus (fig. 56).

The maxillæ are very large and the denticles unusually numerous (115—130). The inner angle of the maxilla (fig. 60, *i*) rises abruptly above the level of the œsophageal fold which it terminates, and the lateral surfaces exhibit a consid-

[1] Ed. Grube, "Anneliden," in 'Reise der Oesterreichischen Fregatte Novara um die Erde in den Jahren 1857—1859,' Zoologie, Abth. 3, B. *ii*, Wien, 1868, pp. 39—40.

erable number of wart-like protuberances. The denticles are straight, conical, and radially directed; the longest (·035 mm.) are placed at the inner angle of the maxilla, from which point they diminish gradually in length towards the external angle, where they vanish in the merest rudiments.

In a specimen measuring 85 mm. in length, the œsophagus measured 6 mm. (excluding the maxillæ); the anterior half shows only three folds, one median dorsal and two latero-ventral. Each of these folds divides into two near the middle of the œsophagus, thus making six folds in the posterior half.

The segmental papillæ are remarkably large, resembling in form, size, and inclination those seen in the Medicinal Leeches of Saigon, Singapore, and Ceylon. In number and position they agree with those of Hirudo. In no other species have I seen such an extraordinary number of these papillæ on the acetabulum. Their arrangement here shows that the acetabulum is composed of at least eight somites, each of which is now represented by a single papillate ring. The abbreviation is thus carried further here than in any other portion of the Leech except in the cephalic lobe.

The median papillæ (*m.*) incline a little towards the median line of the dorsal surface; the inner lateral papillæ incline still more in this direction; and the outer lateral (*ol.*) and the marginal papillæ (*mg.*) have their longer axis directed nearly at right angles to the axis of the body.

I am wholly indebted to Dr. Sluiter for the following description of the colour and markings of this species, which was very imperfectly described by Wahlberg:[1]

"Ground-colour of the dorsal side dull olive green, sometimes inclining more to grass green, at other times more to brownish shades. In the median line of this side there is a series of elongated black spots, from twenty to twenty-five in number, which never blend into a continuous stripe. Towards the head these spots are smaller and often more rounded, while in the middle and posterior region they are more elon-

[1] Öfvers, 'Kongl. Vet.-Akad. Förh.,' Stockholm, 1855, p. 233. Compare Diesing's 'Revision der Myzhelmintheu,' Abth. Bdellideen, p. 38, Wien, 1859.

gated, stretching over three annuli. This series of black spots lies in a broad stripe of a lighter colour than the ground-colour, which is narrowed at each of the intervals left between the black spots. On each side of this broad stripe are two narrow, longitudinal yellowish stripes, each of which is bounded by two narrow black borders. These lateral stripes are interrupted from point to point, so that they do not form unbroken stripes. The entire dorsal surface is flecked with black, and these flecks are more numerous and larger along the yellow margins. The dorsal side of the margin is a clear yellow, while the ventral side is reddish yellow. Often the yellow margins are very regularly dotted with black, a single dot occurring on each ring. A few irregular larger black flecks are also seen scattered along these margins.

"The ground-colour of the ventral side is brick red; just inside the yellow margins of this side are two broad stripes of the same dull green as the ground-colour of the dorsal surface; these stripes are sharply defined against the brick red middle zone by an intermixture of black flecks, which for the most part blend together. The two suctorial surfaces are bluish grey, the oral surface being a little lighter than the posterior sucker. The oral surface has a pale margin, which is not seen in the acetabulum.

"The eyes are placed on the 1st, 2nd, 3rd, 5th, and 8th rings, as in H. medicinalis.

"Length = 175 mm. . . . . .

"I found some Leeches which agreed in general with the above description, but which showed a constant difference in colour, and which are probably to be regarded as a variety. The dorsal surface was less variegated in colour, without the lateral stripes, and darker green. The black flecks and stripes were the same. The ventral surface is not brick red, but of the same green colour as the dorsal side, without the black flecks. The dark stripes inside the yellow margins are broader and have a larger admixture of black. Large and small individuals of both varieties were found, from which we may conclude that the difference is not one of age. Both varieties

are very abundant in the Sawahs (rice-fields), in the water of the low lands around Batavia and elsewhere on the north coast of Java. The Malayan name is Lintah. Both varieties are used for medicinal purposes."

4. Leptostoma.—Three species of Japanese Leeches (Pl. XVIII, XIX, and XX) agree with the forms hitherto mentioned in having twenty-six somites between the first pair of eyes and the acetabulum, but differ from all of them in having fewer abbreviated somites. This peculiarity shows that these Leeches have not descended from Hirudo medicinalis, and that they are entitled to rank as a more primitive type than any of the Hirudinidæ at present known. These Leeches possess certain characters (denticles rudimentary or absent) that suggest relationship with Aulostoma; but Aulostoma is unquestionably an offshoot from Hirudo, and the characters in which it approaches Leptostoma cannot be regarded as evidence of genetic affinity. The rudimentary condition of the denticles and maxillæ, with all the correlated peculiarities, are characters that have been acquired independently by the two genera. Leptostoma and Hirudo, we must assume, had a common ancestral form; and Leptostoma has departed from this archaic form in much the same way that Aulostoma has departed from Hirudo. This seems to me to be the most rational mode of explaining the relationship of these genera.

Pl. XX, figs. 54 and 55, will show the more important characters on which the new genus Leptostoma is based. These figures represent the two extremities of Leptostoma pigrum somewhat diagrammatically. Looking first at the anterior end (fig. 54), we find only five abbreviated somites. These five somites contain the same number of annuli (10) as the corresponding somites in Hirudo; but there is a small difference to be noted in the last ring of the 5th somite. This ring is constantly larger than the other rings, and hence it may be regarded as representing two rings combined. The 6th somite includes five annuli, two more than the same somite in Hirudo. This difference explains other differences; for instance, the position of the first pair of nephridial pores

in the hind edge of the 15th annulus instead of the 13th, and the location of the genital pores between the 32nd and 33rd, and between the 37th and 38th rings. Passing to the posterior end of the body (fig. 55), we find here only three abbreviated somites, the 23rd somite containing the full number of rings. Thus there are eighteen unabbreviated somites (sixteen in Hirudo) and eight abbreviated (ten in Hirudo). It is interesting to note that the abbreviated somites have been abbreviated to very nearly the same extent as in Hirudo. As we have here two more complete somites than in Hirudo, we have 106 annuli between the first pair of eyes and the anus. The nephridial pores occupy the same somites (six to twenty-two inclusive) as in Hirudo, and hold homologous positions; for the 15th and 95th annuli are here homologous with the 13th and the 93rd in Hirudo. The 106th annulus is homologous with the 102nd of Hirudo. The 103rd annulus (99th of Hirudo) is plainly double at its margin, though single elsewhere; and the 102nd annulus is constantly thicker than the preceding ring, which indicates that it represents two rings consolidated. There is abundant evidence that the somites are not abbreviated by a sudden and complete syncopation of one or more annuli; the process is rather a gradual one, consisting in the coalescence of two successive annuli. When a papillate annulus combines with a non-papillate, as seen in the 103rd, the individuality of the latter seems to be suppressed, in subordination to that of the former. In this case (103rd annulus) it is evident that the posterior half of the annulus represents the original papillate annulus, as shown by the position of the papillæ, and thus it becomes plain that two successive annuli of different somites may combine.

Leptostoma edentulum (Pl. XIX) agrees very closely with L. pigrum having 105 rings, and sometimes a fragment of a 106th. The number and abbreviation of the somites are essentially the same. Only one difference requires mention here: in the 23rd somite, the 97th and 98th annuli are often not so plainly divided as the following rings of the same somite. This peculiarity is not apparent in L. pigrum, while

it has been carried one step further in L. acranulatum (fig. 53). Here the 97th annulus represents the 97th and 98th (of L. pigrum and L. edentulum) fully consolidated as may be inferred from its size. We have thus only 104 annuli, with sometimes a trace of a 105th. These three species agree in having five abbreviated somites (embracing ten annuli) at the anterior end, and in the position of the genital orifices and nephridial pores. Their chief point of difference is the degree of abbreviation represented in the 97th and 98th annuli.

5. Macrobdella sestertia,[1] nov. sp.—As the Macrobdella which I have examined differs in some important points from those described by Verrill, Leidy, and Brooks, I shall give a full description of the specific as well as the generic characters.

Diagnostic Characters.

Body has the shape and proportions of Hirudo of Europe, except that, anteriorly, it tapers rather more rapidly. The following measurements were taken from a middle-sized specimen: Length, swimming, 9·5 cm.; in extension, 13 cm.; at rest, 5·8 cm. Width, swimming, 12 mm.

Cephalic lobe, semi-ovate, smaller proportionally, than in Hirudo; composed of four annuli. The thin margin is capable of considerable extension and is slightly emarginated at the tip; it is thickly beset with fine papillæ on its inferior surface. The under side of the cephalic lobe shows three convergent fossæ, one median corresponding to the dorsal maxilla, and two lateral corresponding to the latero-ventral maxillæ. When the Leech is at rest the head is usually rolled into the buccal cavity, as is the habit with all Hirudinidæ.

Acetabulum circular and centrally attached; 6·5 mm. in diameter.

Annuli 103; the last three very imperfectly marked. Most of the annuli appear to be double; but the two halves are separated by a comparatively shallow furrow.

[1] This name is given in allusion to the fact that the sexual openings are separated by two and a half rings.

Buccal Annuli = 5th and 6th; distinct on the ventral side, but not so deeply divided as the following annuli.

Post-buccal annuli = 7th and 8th, distinct below.

Genital Apertures.—The male orifice is in the middle of the 32nd annulus (4th annulus of 10th somite); the female orifice lies between the 34th and 35th (1st and 2nd of 11th somite), separated from the male by two and a half annuli.

Clitellum embraces 9th, 10th, and 11th somites.

Copulatory Glands. ("mucous glands," Brooks).[1]—A quadrangular swollen area occupies nearly the median third of the 41st, 42nd, and 43rd annuli, on the ventral side. This area is divided into an anterior and a posterior half by a groove running along the middle line of the 42nd annulus, so that each half occupies the width of one annulus and a half (fig. 57, Pl. XX). In each half is a row of six small oval areas, pale or flesh coloured, side by side; and in each of these two gland pores. Thus there are twenty-four pores in four parallel rows, as shown in the figure. The anterior row of oval areas stretch across the groove dividing the 41st and 42nd annuli; the posterior row, across the groove dividing the 42nd and 43rd annuli; so that two rows of pores are associated with the 42nd annulus, while the 41st and 43rd have each one row of pores. Six annuli intervene between the female orifice and the glandular area.

Leidy[2] has suggested that the glands opening through these pores are "provided for the adherence of individuals in sexual intercourse," and their position favours this view.

Ocelli.—Five pairs; arranged precisely as in Hirudo.

Œsophagus=about one sixth of the length of the Leech. The number and arrangement of the folds, so far as I could learn from the specimen examined, agreed very nearly with Leidy's description.

Maxillæ.—Three, large; armed with thirty-nine to forty-six acute and slightly curved denticles.

[1] V. K. Brooks, 'Handbook of Invertebrate Zoology,' Boston, 1882.

[2] Leidy, 'Proc. Phil. Acad. Nat. Sci.,' 1868, p. 230.

Nephridia.—Seventeen pairs,[1] located in the same rings as in Hirudo.

Segmental Papillæ.—Beginning with the 5th annulus, which bears the fourth pair of eyes, the papillate annuli are,—5th, 8th, 11th, 14th, 19th, 24th, 29th, 34th, 39th, 44th, 49th, 54th, 59th, 64th, 69th, 74th, 79th, 84th, 89th, 94th, 98th and 100th. Occasionally we find traces of pappillæ on the 102nd. Thus the number of papillate annuli is the same as in Hirudo; but the order is the same only as far as the 94th, which shows a difference in the annular composition of the posterior abbreviated somites.

Each of these annuli, except a few at either end of the body, bears fourteen minute segmental papillæ, eight on the dorsal and six on the ventral half. On the dorsal side (figs. 57, 59, Pl. XX) there are two median (*m.*), four lateral (*il. ol.*), and two marginal (*mg.*); on the ventral side (fig. 58) two median, two lateral, and two marginal.

The median dorsal papillæ, which are smaller and less distinct than the others, can be traced as far forward as the 2nd annulus, being replaced on the 1st by the first pair of eyes. The two inner lateral papillæ (*il.*) are the most strongly developed, and exhibit very plainly a serial relationship with the eyes. The outer lateral papillæ could not be traced farther forward than the 5th annulus. Both the inner and outer lateral papillæ are whitish, and easily seen with naked eye. The marginal papillæ lie in the very edge of the olive green of this side, and are quite conspicuous from having the bright colour of the ventral side. No distinct traces of these were found anterior to the 11th annulus.

The median papillæ of the ventral side are extremely minute, and much farther apart than those of the dorsal side (fig. 58). The lateral papillæ lie directly behind the nephridial pores, and are almost as conspicuous as the pores themselves. Their distance from the margin is about one fourth of the

[1] Brooks states that there are eighteen pairs in the Macrobdella he examined.

width of the body. The marginal papillæ are very close to the edge of the body, and nearly as large as the lateral papillæ.

Colour.—The ventral side is a bright reddish brown, with a few small scattered flecks of black. The ground-colour of the dorsal side is dark olive green. The most conspicuous markings of this side are the median row of orange-coloured spots. The first of these spots forms an elongated patch, beginning on the 1st annulus and stretching back to the 5th. The hind end of this patch is almost constricted off, so that it sometimes appears to represent an independent spot. The entire patch can be regarded as four coalesced spots. Behind this there are twenty of these spots, one on each papillate annulus as far as the 98th. The 100th annulus had no orange spot in any of the specimens examined, but it does have it in some other species. These spots have an elongated form, except when the Leech is much contracted, each one stretching across a papillate annulus and a half or more of the annulus following. The elongation in an antero-posterior direction suggests that they are remnants of a median stripe, which was once continuous over the non-papillate as well as the papillate annuli. The presence of small flecks of yellow scattered sparingly along the median line can be most naturally explained on this hypothesis. Small dark flecks are thickly strewn along the median dorsal area; and these are perceptibly darker on each side of the orange spots, which may be taken as an indication that the hypothetical median stripe had dark borders.

The next most prominent markings are two rows of quadrangular black spots (6), one on each side, considerably nearer the margin than the median line. These spots lie between the lateral papillæ of each side, and are limited, for the most part to the papillate annuli; occasionally, however, they show a posterior elongation, more rarely an anterior one.

Just inside the black spots there is, on each side, a row of faded black spots, irregular in shape, and plainly forming parts of an obsolescent dark stripe.

The very narrow margins of the dorsal surface have the colour of the ventral side.

Habitat.—Found in the neighbourhood of Cambridge; geographical limits unknown.

Abbreviated Somites.—There are twenty-six somites, of which the first six and the last four are abbreviated. The abbreviation at the anterior end agrees with what has been seen in Hirudo. The 24th, 25th, and 26th somites have each two annuli or remnants of annuli, and in so far agree with the Hirudo type. In the 23rd somite we find an important difference between the two genera; for in this somite there are at least four annuli in Macrobdella against three in Hirudo. The second annulus of this somite (95th in fig. 59) must be regarded as two annuli in process of consolidation; as its two halves show a well-marked separation at one (left in the fig.) and sometimes both margins. The two halves are, together, only a trifle thicker than the 94th annulus; but they are much thicker than the 96th. This peculiar double annulus is found in several (perhaps all) other species of Macrobdella. The process of abbreviation has only fairly begun in this somite, and has just reached a point that leaves it doubtful whether we have four or five annuli.

Differential Characters.—The genus Macrobdella is distinguished from Hirudo by the following characters:

1. Copulatory glands.
2. Four (or five) annuli in the 23rd somite.
3. Neither the buccal nor the post-buccal annuli are united on the ventral side.
4. Cephalic lobe smaller.

It remains to be seen whether this genus may be subdivided according to the number of rings separating the sexual orifices.

Leptostoma pigrum, g. et sp. nov. Pl. XVIII, figs. 21—27.

Diagnostic Characters.

Body large and fleshy, tapering towards the head more rapidly than in Hirudo (figs. 22 and 23).

Length of one of the larger specimens, swimming, 16·5 cm.; in extension, 21 cm.
Width „ „ 2 cm.; at rest, 2·5 cm.

Cephalic lobe, as in Hirudo, except much smaller proportionally.

Acetabulum 8 mm. in diameter, relatively smaller than in Hirudo.

Annuli 106.

Buccal annuli=5th and 6th. The coalescence is quite complete in the middle of the ventral side, but towards the margins they are distinct.

Post-buccal annuli=7th and 8th. Generally distinct on the ventral side, but not so deeply separated as the succeeding annuli.

Genital Apertures.—Male orifice between the 32nd and 33rd annuli, two annuli behind the fourth pair of nephridial pores. Female orifice between the 37th and 38th annuli.

Clitellum embraces the 9th (except 1st annulus), 10th, and 11th somites, and one annulus of the 12th somite, making fifteen annuli (twenty-seven to forty-one inclusive).

Anus in the last annulus (106th).

Ocelli, five pairs, arranged as in Hirudo. First pair the largest.

Œsophagus relatively long; with six folds, one dorsal, one ventral, two dorso-lateral, two ventro-lateral. The dorsal and ventro-lateral terminate in the maxillæ. The dorso-lateral folds small at the level of the maxillæ, but larger posteriorly.

Maxillæ three, small, on alternate folds, destitute of proper denticles, but provided with two series of irregular, thin, denticular plates, which are more or less united, especially at the outer and inner angle (*e* and *i*, fig. 62, Pl. XXI), where the two series bend into each other, thus completing the circuit of the outer edge of the jaw. These two series of brownish-yellow chitinous plates correspond to the double roots of the denticles in Hirudo; they rest on a thick muscular welt (*w*., fig. 61), and are very feebly developed at the two angles of the jaw. In the elongated area, inclosed by the plates, numerous small fragmentary pieces of the same colour and texture are seen (fig. 62).

Stomach plainly divided metamerically, but the chambers much smaller than in Hirudo. The posterior chamber prolonged in two narrow lateral diverticula.

Intestine (stomach, Gratiolet) divided anteriorly into four chambers, the first of which is quite as wide as the chambers of the stomach.

Nephridia, seventeen pairs. First pair of pores in the hind edge of the 15th annulus; the seventeenth pair on the hind edge of the 95th annulus. Four pairs in front of the male orifice.

Segmental Papillæ.—Six dorsal and six ventral rows, as in H. nipponia. The papillate annuli, omitting the eye-bearing annuli, occur in the following order: 11th, 16th, 21st, 26th, 31st, 36th, 41st, 46th, 51st, 56th, 61st, 66th, 71st, 76th, 81st, 86th, 91st, 96th, 101st, 103rd, 105th (figs. 54, 55, Pl. XX).

The six dorsal rows are in pairs, one median pair and two lateral (fig. 27 *d*, Pl. XVIII); the ventral rows are arranged as shown in fig. 27 *v*.

Colour.—The dorsal side is brownish olive, with fine dark brown stripes, along each of which are placed, at regular intervals, oval or quadrangular yellow spots. The median stripe is usually darker than the lateral stripes, and in this the spots are sometimes wanting or much reduced in size (fig. 27 *d*). The inner lateral stripe runs midway between the median stripe and the margin, and the outer lateral stripe midway between the inner lateral stripe and the margin. In some cases (figs. 22, 24 *d*, 27 *d*) a shadowy stripe is seen on each side of the median stripe, equidistant from this and the inner lateral stripe; and this, in rare instances, may also be marked by yellow spots (fig. 24 *d*). The margins are usually bright orange yellow, bordered on the inner side with a narrow line of dull brown, or with mere flecks of this colour. The marginal yellow is continued round the acetabulum and the head.

The yellow spots of the median stripe become confluent anteriorly, forming thus an elongated patch which reaches to

the first pair of eyes. The spots of the lateral stripe sometimes blend in a similar manner.

The spots occur on the 2nd and 4th annuli of the somite, so that an interval of one annulus (3rd) alternates with one of two annuli (5th and 1st). Thus ten spots, two in each stripe, are found on each of the unabbreviated somites. This is the typical arrangement of the spots in specimens found about Tokio; but it is occasionally modified by the interpolation of small spots, as shown in figs. 22 and 27 *d*. In specimens obtained from a small lake (Junsainuma) near Hakodaté, in Yezo, the interval of one annulus is filled by a spot, so that three spots occur on successive annuli, followed by two annuli without spots (fig. 24 *d*). This arrangement may occasionally be modified by filling up some of the intervals of two annuli.

The entire absence of these spots in the median stripe of some individuals, the variations resulting from the filling up of the intervals, and their confluence at the anterior end of most specimens, all suggest that they may be regarded as remnants of yellow stripes, such as are seen in H. nipponia.

On the acetabulum one or more broad median patches of yellow are seen, which represent parts of the original stripe, or perhaps confluent spots. These patches are bordered laterally by a narrow wavy line of dark brown or black, precisely as are the spots on the body.

In many specimens dark flecks are scattered along each side of the median stripe (fig. 23).

The ventral surface is generally a dull orange yellow, marked with broad marginal stripes of dark brown with interspersed flecks of black, and with six or more narrow and much broken intermediate brown stripes. The ground colour of this side often varies towards the olive (fig. 27 *v*.) and brown shades (fig. 24 *v*.).

Genital Organs.—The penis lies on the left side of the nerve-chain, just behind the sixth pair of ganglia. The vagina, consisting of a saccular and a tubular portion (fig. 67 *v*.), lies on the right side of the nerve-chain, reaching from near the

7th to the 9th ganglia. The left oviduct passes under the nerve-chain, just the reverse of what happens in H. nipponia. The common oviduct (*od. c.*) and the gland (*gl. alb.*) adhere to the saccular portion of the vagina.

Habitat.—Ditches and ponds around Tokio and Yezo. None found at Aomori. Much less abundant than the common Medicinal Leech.

Habits.—Very sluggish; not easily induced to swim, though swimming well when forced. Food unknown; probably carnivorous.

LEPTOSTOMA EDENTULUM, g. et sp. nov. Pl. XIX, figs. 28—39.

Diagnostic Characters.

Body.—Small, tapering gradually to the very narrow head (figs. 28 and 29).

Length, swimming, 5·5 cm.;	in extension, 7·5 cm.;	abreast, 4·5 cm.
Width	„	1 cm.;	„	6 mm.;	„	9·10mm.

The largest individual found measured, in extension, 12 cm.; swimming 8·5 cm.

Cephalic lobe and anterior portion of body extremely narrow.

Acetabulum 4 mm. in diameter.

Annuli 105, with sometimes a rudiment of a 106th behind the anus.

Buccal annuli = 5th and 6th, united on the ventral side.

Post-buccal annuli = 7th and 8th, united on the ventral side.

Genital Apertures.—Male orifice between 32nd and 33rd annuli—two annuli behind the fourth pair of nephridial pores. Female orifice between 37th and 38th annuli.

Clitellum 9th, 10th, and 11th somites.

Anus cuts the 105th annulus.

Ocelli five pairs, as in Hirudo.

Œsophagus has six folds, one dorsal, one ventral, two dorso-lateral, two ventro-lateral.

Maxillæ three, very small, only a little higher than the

folds to which they belong (fig. 63, Pl. XXI), showing absolutely no trace of denticles or rudimentary plates.

Nephridia seventeen pairs; first pair in the 15th, last pair in the 95th annulus. Four pairs in front of male orifice.

Segmental papillæ in six dorsal and six ventral rows. The papillate annuli have the same number as in the preceding species.

Colour.—The ground colour of the dorsal side is in the majority of cases a rich chrome green, sometimes exhibiting an exquisite shade of dark blue (fig. 28), more rarely inclining to the dull olive hue of fig. 39. There are five longitudinal stripes, one median and on each side two lateral. The median stripe is the broadest and most conspicuous, and is continuous from the first pair of eyes to the hind edge of the acetabulum. It is usually a brilliant chrome yellow, sometimes a gamboge yellow, or a bright golden yellow. It is bordered on each side by a narrow line of black, which is not sharply outlined.

The lateral stripes are always narrower, generally duller; and sometimes one or both of them (more frequently the inner one alone) are obsolete or obsolescent. As a rule, the lateral stripes, when present, are interrupted on every 5th annulus by the approximation of the black borders (figs. 33 and 37); and when absent are replaced by a black stripe, which represents the two borders united. These stripes are partially obliterated in fig. 28, wholly so in figs. 31 *d*, 32 *d*, and 34.

The narrow margins are yellow, generally paler than the median stripe.

The ventral side exhibits various shades of green and olive, more or less thickly sprinkled with black flecks. Alongside the yellow margins these flecks are so numerous that they might almost be said to form broad black borders.

A specimen from Aomori, the only one found in this locality, was very dark green, with a bright median yellow stripe and black lateral stripes (fig. 31).

Habitat.—Found in shallow pools in the rice fields around Tokio. Only one specimen found in Aomori, and none in Yezo. Comparatively rare.

Habits.—Active, easily provoked to swim. Food unknown.

Internal Organs.—The female organs (fig. 66, Pl. XXI) are in every respect similar to those of H. nipponia. The vagina is sometimes on the right, sometimes on the left of the nerve-chain.

The stomach is a narrow straight tube, with no distinct division into chambers, with two long slender diverticula at the posterior end. The intestine is divided into three regions of nearly equal length. The first is much wider than the stomach, and is divided into four chambers; the second is a narrow middle piece with a single coil; the third is a dilated fusiform end piece.

The dermal glands are larger and more numerous on the dorsal than on the ventral side.

The nephridial vesicles are large, and lined with a ciliated epithelium. The cilia appear to be absent in the region which leads into the efferent duct.

This beautiful little Leech agrees with a few forms found elsewhere in having no denticles; but this character appears to me to have comparatively little value as a generic distinction; certainly, much less than the number of its abbreviated somites, which links it with L. pigrum and L. acranulatum.

Toothless leeches have been found in various and widely-distant parts of the earth, which, so far as the descriptions go, differ from one another in important particulars. Philippi[1] describes a gigantic leech (?) from Valdivia, under the name of Macrobdella valdiviana, which has neither eyes nor jaws. Grube[2] has described a curious subterranean form (Cylicobdella lumbricoides), also without eyes or jaws. Cyclobdella glabra[3] is said to have ten eyes, but no jaws; and Hylobdella, Doringii, and H. flavolineata are reported

[1] Halle'sche, 'Zeitschr. f. d. gesammten Naturwissenschaften,' vi, pp. 435—442, 1872. Cf. 'Leuckart's Bericht,' 1872—1875.

[2] 'Arch. f. Naturgesch.,' pp. 87—121, 1871. 'Leuckart's Bericht,' 1870—1871.

[3] 'Boletin de la academianacional de ciencias de la repub. Argentina,' iii, pp. 231—244. According to 'Leuckart's Bericht.'

to have one pair of eyes and no denticles. Several species of Bdella have been said to be without denticles; but Peters,[1] according to Leuckart, affirms that denticles are present. In Leuckart's collection is a Leech labelled Bdella nilotica[2] from Port Natal. The œsophagus has six folds, and three small edentate jaws on alternate folds. Paired rudiments of denticular roots were found along each side of the median crest of the jaw. This Leech has the large oval segmental papillæ seen in H. saigonensis, H. maculosa (Singapore), H. javanica, H. multistriata (Ceylon), with the same inclination shown in fig. 56, Pl. XX.

Kinberg has described three species with "edentate maxillæ,"—D. decemstriatus from Montevideo, D. natalensis from Port Natal, and D. maculatus from Wisconsin.

Verrill[3] found "no distinct maxillæ" in Lemiscolex grandis, and mentions none in the case of Hexabdella depressa.

LEPTOSTOMA ACRANULATUM, g. et sp. nov. Pl. XIX, figs. 40—46.

Diagnostic Characters.

Body attains a greater length than in H. nipponia; general form and proportions are the same.

Length, swimming, 9-10 cm.; in extension, 12-15 cm.; at rest, 7-8 cm.
Width „ 10 mm.; „ 7 mm; „ 14 mm.

Cephalic lobe smaller than in Hirudo, but larger than in L. edentulum.

Acetabulum comparatively small, circular, 3 mm. in diameter.

Annuli 104, with sometimes a trace of a 105th behind the anus.

[1] 'Berl. Monatsber.,' 1854. 'Leuckart's Bericht.,' 1854-5, p. 359.

[2] Is not this Democedes natalensis, Kinberg?

[3] 'American Journal of Science,' iii, p. 136, 1872; 'Report of Com. of Fish and Fisheries,' for 1872-73, pp. 672, 673.

Buccal Annuli = 5th and 6th, united at the middle of ventral side, but distinct towards the margins.

Post-buccal Annuli = 7th and 8th, fully united below.

Genital Apertures.—Male orifice near the middle of the 34th annulus (4th of the 10th somite), three and a half annuli behind the fourth pair of nephridial pores. Female orifice in the 39th annulus (4th of the 11th somite).

Clitellum.—Limits not determined.

Anus behind the 104th annulus; sometimes cuts deeply into the hind edge of this annulus.

Ocelli, five pairs, as in Hirudo.

Œsophagus has six folds.

Maxillæ, three, on alternate folds, furnished with from ten to fifteen pairs of rudimentary denticular roots (fig. 45). In some cases the roots are united, the pair forming then a single transverse plate. In some individuals I found either no traces of rudiments or only a few scattered fragmentary remnants.

Nephridia, seventeen pairs, beginning in the 15th and ending in the 95th annulus; located nearer the middle than the hind edge of the annulus.

Segmental papillæ, in six dorsal and six ventral rows. The papillate annuli have the same number up to the 96th as in L. pigrum; the remaining three are the 100th, 102nd, and 104th, instead of 101st, 103rd, and 105th. This is accounted for by the coalescence of the 2nd and 3rd annuli of the 23rd somite (fig. 53). These two annuli are still distinct in L. edentulum, but they are not so strongly divided as the following annuli. The papillæ are extremely small (figs. 41 and 42) as in the two preceding species.

Colour.—The ground colour of the dorsal side is olive or olivaceous brown. There are five stripes, one median and four lateral. The broad median stripe is constant and often very conspicuous, owing to the metameric broadening of its black borders (fig. 41). This stripe is a pale olive or brownish olive, usually a lighter shade of the ground-colour itself. Its dark borders generally swell at regular intervals, as shown in Pl. XIX, fig. 41; but this peculiar pattern is often imperfectly

developed, as in fig. 44, and, in some cases, is scarcely more than indicated in shadowy and faded colours (fig. 46). The lateral stripes are narrower and duller, and often scarcely differ from the ground-colour, their position, then, being recognisable by their dark borders. These stripes are constricted at every annular groove, and sometimes quite interrupted at these points, the dark borders becoming confluent, and forming thus a chain of oval areas (fig. 41). The margins (embracing a narrow area on both the dorsal and ventral side) are orange yellow, olive, or brownish yellow bordered on each side by irregular dark brown flecks.

The ventral side is olivaceous, and sometimes marked by a few scattered flecks of dark brown.

Habitat.—Abundant in the rice fields and ditches about Tokio. Found also in Aomori, but not in Yezo.

Habits.—Active. Food not known.

Internal Organs.—The male organ opens between the 6th and 7th ganglia (beginning with the sub-œsophageal); the female between the 7th and 8th. The ovaries do not lie near the anterior end of the vagina, as they do in all the foregoing species, but have shifted their position to a point just before the 12th ganglia (Pl. XXI, fig. 64). Both the vagina and penial pouch are very long. The vagina is not plainly differentiated into a saccular and a tubular portion, but its posterior half is somewhat larger than the anterior. The oviducts are concealed by a large ovate glandular mass (*gl. alb.*), which lies diagonally across the nerve-chain, concealing the 10th ganglia. The common oviduct (*od. c.*) issues from the small end of the albuminiferous glands, makes a few bends and enters the hind end of the vagina (*v.*).

The vas deferens (*v. d.*) of either side passes into a coiled portion, the vesicula seminalis (epididymis), near the level of the ninth pair of ganglia, emerges in the form of a long trumpet-shaped portion (*d.*), the ductus ejaculatorius, which tapers gradually into the narrow terminal portion of the efferent duct. This terminal part of the seminal duct passes forward to near the sixth pair of ganglia; then, making a short

bend, runs back along the dorsal side of the penial pouch (*p.*), and enters the pouch near its hind end, passing first through the so-called glandulæ prostaticæ.

The stomach, or that portion of the alimentary canal corresponding to the "stomach" of Hirudo, is a straight tube, showing (in alcoholic specimens) no trace of metameric division, and terminating behind in two slender diverticula, the length of which was not ascertained. Just behind the junction of the diverticula with the main canal, the intestinal portion begins to enlarge; and a litle farther back it becomes smaller, tapering quite gradually to the very end. The intestine may be described as a fusiform canal, not differentiated, so far as I could see, by superficial examination into regions, and showing no evidence of metameric constrictions.

Segmental Papillæ.

Literature.—The segmental papillæ of the Leech have been noticed by a considerable number of naturalists; but no one, so far as I have been able to learn, has suspected that they were sense-organs. Ébrard,[1] who has described and figured them, gives us no information in regard to their structure, and entirely overlooked their serial relationship with the eyes.

Thomas[2] recognised two of these on the dorsal half of every 5th ring, and tried in vain to inject them.

Fermont[3] found six or eight of these on the dorsal half of every 5th ring, and pointed out the fact that the papillate rings follow immediately the rings in which the nephridial pores are located. "It is necessary," he says, "in order to see them well, to examine a large Leech which has been immersed in boiling water, after having been gorged with blood."[4]

[1] Ébrard, 'Nouvelle Monographie des Sangsues Médicinales,' Paris, 1857.

[2] Thomas, P., 'Mémoires pour servir à l'histoire naturelle des Sangsues,' Paris, 1806.

[3] Fermont, 'Monographie des Sangsues Médicinales,' Paris, 1854.

[4] The works of Thomas and Fermont are known to me only through Ébrard.

The dorsal papillæ were also noticed by Savigny.[1] In describing Hæmopis, he remarks: "On remarque sur le dos de cette espèce des points saillans et diaphanes, rangés transversalement, au nombre de six ou environ, sur certains anneaux; il y en a d'abord sur le neuvième et le douzième, puis sur le dix-septième, le vingt-deuxième, le vingt-septième, et ainsi de cinq en cinq jusqu'au quatre-vingt-douzième inclusivement, après lequel on en trouve encore sur le quatre-vingt quinzième et le quatre-vingt-dix-septième.

"Ces points brillans, qui correspondent précisément aux vingt paires de pores situées sous le ventre, ne sont point particuliers à cette Sangsue, ni même au genre Hæmopis; on les voit très-bien sur les Sangsues médicinales et officinales" (p. 116).

Ébrard (l. c. p. 95) has described the ventral as well as the dorsal papillæ, and has correctly stated their number:—"Ces points blanchâtres existent, tous les cinq plis transverses, au nombre de huit sur le dos, de six à huit sous le ventre. Les deux du milien du dos sont très-visibles à l'oeil nu chez plusieurs Sangsues de la Hongrie, du Levant, d'Espagne et de Géorgie (figs. 51, 33), dont la couleur du dos est noirâtre. Tous sont trés-apparents sur les Sangsues noires de la Bresse, de la Bretagne et sur celles de la Suède; ils constituent les taches blanches qui out été signalées chez ces dernières annélides par M. le professeur Wahlberg."

Gratiolet (l. c., pp. 12, 13) mentions only the median dorsal papillæ as whitish spots, which mark the 1st ring of each somite ("zoonite").

Serial Homology with the Eyes.—In the Hirudo, Aulostoma, and Hæmopis of Europe, as well as in Macrobdella of America, and the Hirudo of Japan, the segmental papillæ are quite small, especially towards the ends of the body, and hence a close examination is required to make out their true relation to the eyes. In the Land Leech of Japan they are more strictly papilliform, and proportionally larger

[1] Savigny, Jules-César, 'Système des Annelides, principalement de celles des côtes de l'Egypte et de la Syrie.'

than in any of the aquatic Leeches. In other Land Leeches they are also very strongly developed, though somewhat less prominent than in the Japanese species. In the Medicinal Leeches of Saigon, Singapore, Java, and Ceylon, they are much larger than in the European Hirudo, and their homology with the eyes is here clear and unmistakable.

The large Medicinal Leech of Saigon, which I shall call Hirudo saigonensis, is one of the most favorable objects for the study of the topographical relations of the segmental papillæ, and from it the accompanying diagram (fig. 1) has been constructed. The papillæ are indicated by black dots, and the eyes by larger dots. On the 11th, the 14th, and the 19th rings there are eight dorsal papillæ, and on the 8th only six; but here it is plain that the fifth pair of eyes (*oc* 5) occupy the places of two inner lateral papillæ (*il*).

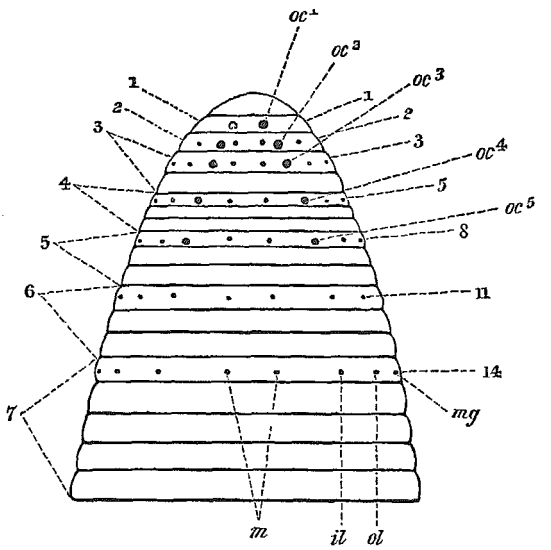


FIG. 1.—Diagram of first seven Somites of Hirudo saigonensis.—The figures at left of diagram indicate the somites; those at the right mark the first ring of each somite. *oc* 1—5. Five pairs of eyes. *m.* Median papillæ. *i. l.* Inner lateral papillæ. *o. l.* Outer lateral papillæ. *mg.* Marginal papillæ.

The same is true of the second, third, and fourth pairs of eyes. The first pair of eyes (*oc* 1) occupy the place of two median papillæ (*m.*), unless the appearances are deceptive. It is, of course, possible that the median papillæ of this ring have been lost, and that the eyes have developed from inner lateral papillæ. The appearances seem to me to favour the opinion that they have been derived from a pair of median papillæ. The papillæ are not round, but oval, and inclined as in Hirudinaria javanica (fig. 56, Pl. XX).

The median papillæ are arranged in metameric pairs, and the distance between the two rows is about the same as that between the first two eyes. Between the two rows of lateral papillæ on each side the distance is about half as great as between the inner lateral row and the median row. The marginal papillæ are placed at the extreme edge of the body. The outer lateral papillæ (*ol.*) are not recognisable on the first ring, and the marginal papillæ are absent on the 1st and 2nd rings; but their presence on the remaining rings (3rd, 5th, and 8th) makes it plain that all the eyes, except perhaps the first pair, occupy the place of the inner lateral papillæ.

Structure.—In comparing the Land Leech with the Medicinal Leech, I have already described the structure of the segmental papillæ. Sections of Macrobdella throw some light on the nature of what I have called the "white corpuscle" in the large clear cells which form the central portion of the eye, and which are associated with the segmental papillæ and with the "goblet-shaped" organs of the lip.

Fig. 71, Pl. XXI, shows two of these cells from the eye. In one of these the "white corpuscle" appears in the form of three bubble-like vesicles or vacuoles. In some cells I find as many as six of these spherical vacuoles, each bounded by a thin but distinct film. These spaces contain a watery fluid which does not stain in the least. The protoplasm of the cells is granular, and forms a peripheral layer, thickened on one side, as shown in Leydig's figures. In this thickened portion which projects into the vacuolar space, may be seen a small oval area, somewhat more darkly shaded. The outline

of this area is not very sharp. Possibly it represents the terminal portion of a nerve, but I have obtained no evidence in support of this view.

The small oval or elliptical nucleus (*n.*) is usually found at the base of the thickened portion of proptoplasm.

Function.—Ébrard ventures the following suggestion as to the function of the segmental papillæ. "Il se pourrait que ces parties fussent les analogues rudimentaires des houppes respiratoires ou autres que plusieurs des annélides dorsi-branches, je citerai les amphinomes, portent sur chacun des anneaux du corps."

I have shown that they are sense-organs, and that from them the eyes have developed. I have not discovered any sense-hairs belonging to these organs, but I have found that a branch of the lateral nerves runs to each of them. For reasons before mentioned, I think it probable that they represent incipient eye-spots.

Postscript.

The unavoidable delays that have prevented the earlier publication of this paper have afforded time for a renewed study of the segmental sense-organs; and the results obtained enable me both to enlarge and to modify to some extent my general conclusions on their function. These conclusions, as presented in the foregoing pages, were based first of all on the serial homology of the segmental sense-organs with the eyes, and second on their structure as ascertained from sections of the Land Leech. A study of these organs in Clepsine has thrown new light on their structure in Hirudo and closely-allied genera. By the aid of a few diagrams I shall endeavour to make clear their more prominent features in both classes of Leeches, and shall then offer a few further considerations relative to their function. I find only six distinct rows of segmental sense-organs on the dorsal side of Clepsine, corresponding to the median, inner lateral, and outer lateral of Hirudo.

On the ventral side, where they are much smaller and more

simple in structure, I have not been able to distinguish with certainty more than four rows, but think it not improbable

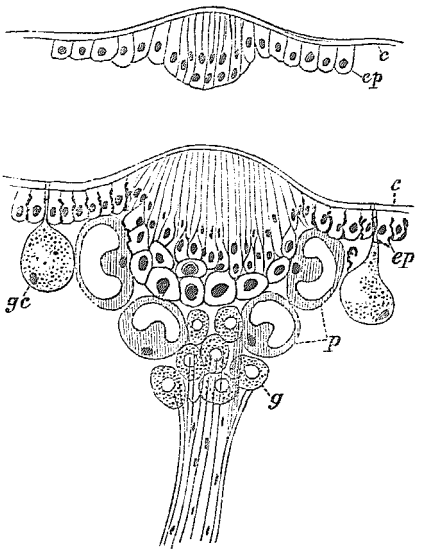


FIG. 2.—Section of one of the marginal sense-bulbs on the ventral side of Clepsine. The nerve and the large clear cells are not represented.

FIG. 3.—Diagrammatic section of one of the inner lateral sense-bulbs of the dorsal side of Clepsine.

c. Cuticle. *ep*. Epidermic cells. *gc*. Gland cells of the epidermic layer. *g*. Nerve-ganglion cells. *p*. Large clear cells, similar to those found in the eyes.

that more careful searching, assisted by sections, may bring to light two more. Fig. 2 gives a section of one of the organs placed very near the margin on the ventral side, and Fig. 3 represents a constructed section of one of the inner lateral sense-bulbs of the dorsal side. The organs of this row are not only larger, but more highly developed than those of the other rows.

The relative prominence of a single row of these organs on each side, so well marked in the Clepsine I have examined,

indicates a correspondingly higher functional importance. Carry this disparity in development and functional value to the extreme, and the result would be a single series of lateral-line organs on each side, as in the case of the Capitellidæ (Eisig). The presence of several rows equally developed on each side appears to me to represent an earlier condition than that of a single row, since it is more easy to account for the disappearance of one or more rows than to explain their independent origin in animals that have had a common derivation. Assuming that some ancestral form possessed several series of lateral-line organs, we should naturally enough expect to find variation in the number of series preserved in derived forms, some perhaps preserving all, while others preserved only a part or none at all. This view seems to me the most satisfactory way of accounting for the occurrence of more than one series of lateral-line organs in the Amphibia and some Fishes.

The structure of the segmental sense-organs of Clepsine is fairly shown in Figs. 2 and 3. The organ represents a bulb-like thickening of the epidermis, supplied with a branch of the lateral nerve of the corresponding body segment. The outer face of the bulb rises as a rounded prominence above the general surface; the inner, more strongly rounded face is cushioned in the connective tissue that intervenes between the epidermis and the ring muscles. Imbedded in this connective-tissue receptacle are a number (four to eight) of very large clear cells (*p.*), differing in no respect from the large cells found in the eyes. These cells are loosely placed around the bulb and nerve, and often one or more of them may be seen at a little distance from the bulb, either below it, alongside the nerve, or to one side. I have nothing to add to what is known about the structure of these peculiar cells, except that they are nucleated (a point disputed by Ranke). I regard them as the morphological equivalent of the epidermal gland-cells (*g. c.*), and therefore as belonging primarily to the epidermis. At the base of the bulb, often extending to a greater depth than shown in Fig. 2, are to be seen in most of my preparations some rather

large rounded cells (*g.*) which appear to be ganglionic in nature. The peripheral cells of the bulb are densely packed, thread-like cells, with pyriform inner (nucleated) ends. The terminal portions of these cells present a rod-like appearance in the apical region of the bulb, and are here more highly refractive than elsewhere. The cuticle extends over the whole external surface of the bulb, but becomes very thin over the circular apical area which is marked by the refractive rod-like ends of the sensory cells. So far as I have been able to learn, these elongated peripheral cells of the bulb are never prolonged beyond the cuticle. The same rod-shaped, refractive end portions are seen in the goblet-shaped sense-organs of the lip and in the eyes.

In Hirudo and Hæmadipsa these organs have the form seen in Fig. 4. The same elements enter into the composition of the organ. The sense-cells are more elongated, and often collected in small groups, to each of which runs a distinct branch of the nerve.

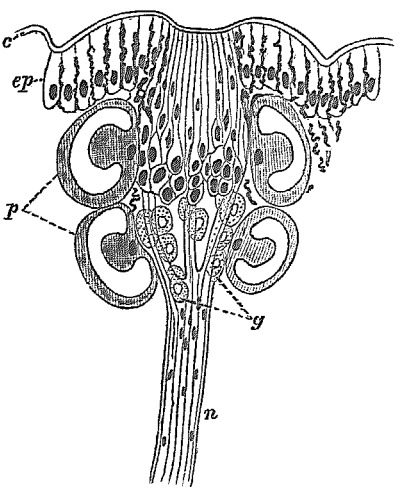


Fig. 4.—Section of one of the inner lateral sense-organs of Macrobdella in a state of retraction. *c.* Cuticle. *ep.* Epidermic cells. *g.* Ganglion cells. *p.* Large clear cells. *n.* Nerve-fibres.

The so-called goblet-shaped organs of the lips differ from that seen in Fig. 4 only in being more strongly developed and in having no large clear cells around the peripheral sensory

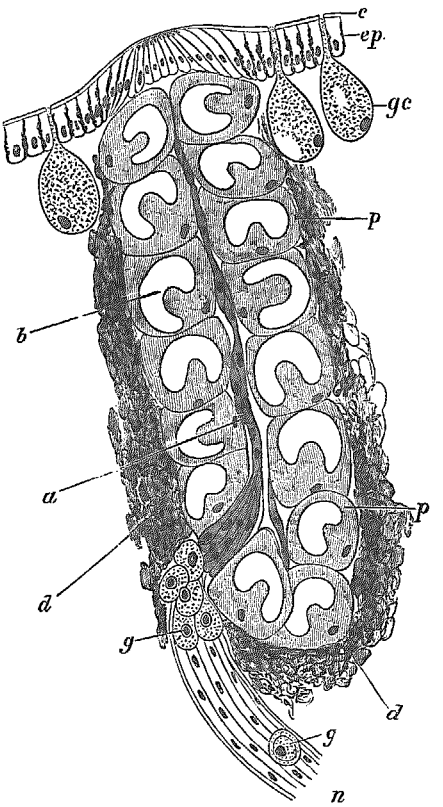


FIG. 5.—Diagrammatic section of the eye of the Land Leech. *c.* Cuticle. *ep.* Epidermic cells. *gc.* Gland-cells of the epidermic layer. *g.* Nerve-ganglion cells. *d.* Pigment. *n.* Nerve-fibres. *p.* Large clear cells. *a.* Nuclei of the same. *b.* Refringent substance of the same.

cells. I have found, however, some of these peculiar cells along the nerve-branches running to these organs.

With respect to the structure of the eye and the morphological significance of the elements composing it, my studies

lead to conclusions fundamentally different, in some important particulars, from those reached by Leydig and Ranke. It is not my intention to deal with details of history and criticism here, and I shall only call attention to points of special interest and importance in forming a correct notion of the eye. In passing, it may be worth while to call attention to some of the figures given by the above-named authors, in order to show wherein they are, in my opinion, misleading. In the first place, Leydig, whose figures are by far the most instructive of any that have yet been published on this subject, describes the sense-organs of the lip and head as goblet-shaped ("becherförmige Organe") organs with a shallow rounded cavity opening at the peripheral end. This cavity, which is only a depression resulting from retraction of the organ (see Fig. 4), is about the only justification for comparing these organs to a goblet. In a state of functional activity, all the sense-organs of the Leech are protruded, so that the peripheral end forms a convex surface (Figs. 2, 3 and 5) as was stated long ago by E. H. Weber. This cup-shaped depression of the retracted organ was supposed to be open at the bottom, the epidermic wall of the cup having a central circular perforation, in which the optic nerve terminated "unbedeckt." The optic nerve, penetrating the eye at the base, is represented as an "Achsenstrang" running the entire length of the eye. Placing the eye so that he could look directly into the cup-shaped depression, Leydig saw, through the supposed opening at the bottom of the depression, a peculiar spot somewhat broader in extent than the "axis-string" seen in transverse section. In preparations treated with reagents, this spot presented a granular aspect, while in a fresh condition it appeared to be composed of "glänzenden Kügelchen," which represented the terminations of nerve-fibres. Ranke gives a diagrammatic section of the eye, in which he leaves the epidermal cover entirely away, and says nothing about a central perforation. Now the peculiar spot seen by Leydig is probably the apical area seen in Fig. 5, in which the central cells of the epidermic cap present refractive rod-shaped ends. This interpretation is the only one

which appears to me to reconcile Leydig's fig. 2[1] (pl. iii) with an actual longitudinal section of the eye.

Ranke's fig. 8[2] (pl. x.) presented one feature that should be noticed here, namely, a ganglion opticum, placed not at the base of the eye, but near its external end.

Between the so-called ganglion and the epidermal cap of the eye only two layers of the large clear cells (P. in my fig.) intervene, while as many as eight lie between it and the base of the eye. The large clear cells in front of the ganglion are supposed to function as a cornea and lens, and to throw images of external objects on the retinal area ("ganglion opticum"). I find nothing in my sections at all comparable with Ranke's optic ganglion, unless it be the axial fibres seen in section. With the ganglion placed near the peripheral end of the eye, as in Ranke's figure, and on the supposition that the large clear cells which lie in front of it serve the purpose of a cornea and lens, the great mass of these clear cells lying behind the ganglion would appear to be useless. This fact alone invalidates Ranke's interpretation and lends some weight to the suggestion that his ganglion opticum was only a sectional view of the axial fibres.

The point on which I differ most widely from Leydig and Ranke lies in the interpretation of the axial fibres of the eye. I regard these fibres as very much elongated sense-cells, derived primarily from the epidermis, and in no sense of the word representing nerve-fibres. My reasons for this view are briefly the following: 1. The optic nerve is at least three times as thick as the widest place in the axial cord of fibres. 2. In a preparation treated with chromic acid twelve hours, washed in water twelve hours, gold chloride one hour, formic acid forty hours, I find that the optic nerve has a decided pinkish colour, while the axial fibres of the eye are stained blue, like the large clear cells and the epidermal cells. These two facts show quite conclusively that the axial fibres are not a direct continuation of the optic nerve.

[1] 'Tafeln zur Vergl. Anat.,' Tübingen, 1864.

[2] 'Zeitschr. f. wiss. Zool.,' xxv, 1875.

Comparing now the eye with one of its serial homologues, a segmental sense-organ, we find that the axial fibres occupy the same position with relation to the nerve and the large clear cells as the sensory cells of the segmental sense-organ. What is more natural than to regard the axial fibres as the sensory cells of the eye? I have sections in which the sensory cells of the segmental sense-organ could scarcely be distinguished if placed side by side with the axial fibres. Nuclei are seen along the axis of the eye, which appear to occupy the enlarged ends of the axial cells. This is best seen in deeper cells, which appear to be continuous with the fibres of the optic nerve. In none of my sections have I been able to trace the axial fibres (or cells) up to the epidermal cap, but I do not think it certain that they do not reach the shorter central cells of the cap. If they are completely separated from the epidermis, this would not of course be any obstacle in the way of accepting the view I have presented.

In the epidermal cap it is necessary to distinguish a central or apical area of relatively short and nearly perpendicular cells from a border ring of longer and strongly convergent cells. The cells of one area pass insensibly into those of the other, the length and degree of convergence increasing from the centre outward, so that they cannot be said to be sharply defined. The short, refractive, rod-like terminations of the central cells to which attention has already been called, enable one, however, to distinguish quite easily the two areas. In a retracted state the cells of the outer area, or border ring, are strongly inclined towards a horizontal position; and when seen from the surface they appear to radiate from the central area precisely as they are represented in Leydig's figures.

The central area then corresponds to what Leydig mistook for a perforation of the epidermal cap, in which the axis-fibres terminated.

From this point of view the eye appeared to be a sac-like invagination of the skin, in which the epidermis was represented by an inner wall of large clear cells and the corium by a thin limiting membrane ("sclerotica") and a thicker pig-

mented layer ("chorioidea"). This conception of the eye was rendered all the more plausible by the supposed central perforation of the epidermal cap, which remained permanently open, while the rest of the lumen of the sac was filled by the axial fibres. It was thus that Leydig maintained that the large clear cells were modified epidermic cells, an opinion in which Ranke fully concurs. According to the view I have presented, the eye is a solid ingrowth of dermal elements, the epidermis being represented by an axial cord of sensory cells continuous at the base of the eye with the optic nerve, the gland-cells of the skin by the large clear cells forming the bulk of the eye, and the sub-epidermal connective tissue by the pigment layer. I have not been able to satisfy myself from my sections that a distinct membrane-like layer (Leydig's sclerotica) separates the pigment investment from the large clear cells. It remains to be seen how far this view represents the actual developmental history of the eye.

Structurally considered, we are able to distinguish at least three different classes of sense-organs in the Leech. The first class embrace the segmental sense-organs of the body and head, and the non-segmental sense-bulbs scattered over the upper surface of the head; the second is represented by derivatives from segmental sense-organs, the eyes; and the third includes the goblet-shaped organs of the margin of the lip. In the first and third classes a bulb-like thickening of the epidermis forms the larger part of the organ, and the chief distinction between them lies in the presence or absence of large clear cells around the bulb. The distinguishing feature of the second class is the massive development of the large clear cells.

With respect to arrangement all these organs may be grouped in two divisions, one of which is strictly segmental, the other non-segmental or accessory. All agree in representing primarily more or less specialised portions of a common morphological basis, but the bilateral and metameric symmetry of one set of organs must be regarded as a distinctive feature of considerable significance. For while the source of origin is

certainly the same, the time and conditions which brought the two sets of organs into existence cannot be identical in all respects.

In respect to time of origin, the segmental sense-organs must be placed first, for the non-segmental organs are limited to a specialised part of the animal, and have undoubtedly arisen in response to the increased needs of this part. There is not the slightest reason to suppose that they owe their origin to a multiplication of the segmental sense-organs by division. On the contrary, it seems quite certain that they must have arisen quite independently.

Before considering the question of function, there are a few points of comparison to be noted between these organs and the lateral-line organ of the Fish.

In the Teleostean Fish these organs pass through, in their early development, a stage which is identical with the simple epidermal thickening that remains permanent in Clepsine (see Fig. 2). In a somewhat later stage (Fig. 6) the peripheral cells develop hair-like extensions, which coalesce to form a

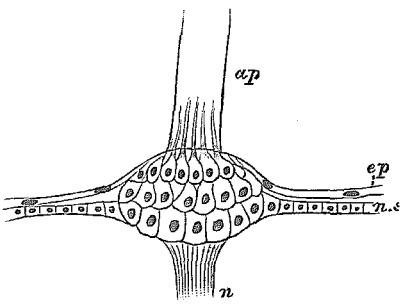


FIG. 6.—Lateral-line organ of a Teleostean Fish at the time of hatching. *ap.* Strap-shaped appendage. *ep.* Epidermis. *n.* Nerve. *n. s.* Nervous stratum.

delicate strap-shaped appendage. The addition of such a mechanism for raising the sensory power of the cells in a special direction does not of course, in view of the facts now well known in regard to the morphology of sense-organs,

make it any the less probable that the lateral-line organs are homologous with the segmental sense-organs of the Leech.

In respect to the nerve supply of these organs, a modification of its segmental character has been brought about in the head of the Leech analogous to what is seen in the body of the Fish. As is now well known, the lateral-line organ of the head of the Fish are each supplied with a segmental nerve-branch, while those of the body are supplied with branches from a single lateral nerve. In the Leech the segmental sense-organs of the body are each supplied with a segmental nerve-branch, while in the head (cf. Leydig's fig. 5, pl. ii) we find a single nerve sending branches to two or more segmental sense-organs, and the same nerve supplying one or more pairs of eyes and numerous goblet-shaped organs of the lip. In this latter particular we have a good illustration of the fact that nerves are not functionally differentiated according to the different sense-organs they supply.

The facts here presented appear to warrant the opinion that at least three different functions are represented in the sense-organs of the Leech. The evident serial homology of the eyes with the segmental sense-organs, and the presence of large clear cells in both classes of organs, suggest that the different sense-organs may not be limited to the exercise of a single function. This view has been put forward by Ranke on the ground that the different sense-organs have been derived from a common morphological basis. It must be admitted that they originally exercised one or more functions in common; and their structural differences, while indicating plainly that they have made some progress in the direction of specialisation, are not so great as to exclude the possibility, or even the probability, that they are still able to do several kinds of work in common. With Claus I regard the goblet-shaped organs of the lip as organs of taste; but it seems almost certain that they function also as tactile organs, as was maintained by Leydig. When blood is placed in contact with the lip of the Leech its behaviour plainly indicates that it has the power of taste. In creeping about the lip is protruded, and the margin,

in which the goblet-shaped organs are located, is plainly used as an organ of touch.

I have never seen any evidence that the eyes are employed either for taste or touch, and the observations of Ranke on this point appear to me to have little value. If the structure of the eye is what I have represented it to be, it is plain that it is not adapted for receiving images of external objects. At most there can only be the power of distinguishing light from darkness, and this power the Leech certainly possesses.

There is still much uncertainty respecting the functional nature of the segmental sense-organs. It is quite certain, however, that they do not serve the same purpose as the lateral-line organs of the Fish or the segmental sense-organs of the Capitellidæ. This point is made certain in two ways; first, by the absence of sense-hairs, and second, by the fact that Land Leeches are provided with these organs. It seems also quite clear that their chief function is not that of tactile organs, for they are not more sensitive to touch than other parts of the epidermis. Their structure is in some respects much like that of organs of taste, but they certainly could not serve the Land Leech in this capacity. Excluding then the three senses of touch, taste, and hearing, there remain those of sight and smell, both of which would be very useful to both land and aquatic Leeches. The eyes are undoubtedly visual organs, but they alone are not sufficient for the obvious needs of the Leech. One of the most characteristic habits of Leeches in general is that of keeping themselves in dark or shaded places. It is not enough to screen the head from the light; the whole body, including the posterior sucker, require to be so protected in order to satisfy fully the usual conditions of rest. This is particularly true of Clepsine and Hirudo, and only a little less so of Nephelis.

But how is it possible for Leeches to know when these conditions are fulfilled for all parts of the body? This question is answered, if the segmental sense-organs are capable of distinguishing light and darkness. The massive development of the large clear cells in the eyes is very conclusive evidence that

their special function is more or less intimately associated with the work performed by the eyes. Although I do not feel prepared to adopt without reserve the opinion that they represent simply a dioptric mechanism, I think their presence in the eyes and the segmental sense-organs furnishes good ground for thinking that both classes of organs have a common function. Add to this their serial homology and the evidence becomes stronger in favour of the view maintained in this memoir respecting the function of the segmental sense-organs.

But how are we to explain the presence of the same large clear cells along the nerve-branches running to the goblet-shaped organs of the lip? They are not here associated with the peripheral sensory cells, as they are in the eyes and the segmental sense-organs, and I am not certain that they are constant. All that I can say is that they are to be seen in some of my sections of the Land Leech, and I confess to being quite unable to offer any explanation of them in this position.

While still maintaining that the segmental sense-organs, as well as the non-segmental sense-bulbs scattered over the upper surface of the head, share in the work of the eyes, I am strongly inclined to think that this is not their only work. In the case of the Land Leech I have obtained some evidence of a sense of smell. A breath thrown into the bottle containing these Leeches instantly puts them into a state of very great excitement. They move about in great haste, as if aware of the presence of some object tempting to their appetite. Any jar of the bottle is sufficient to excite them, but disturbance of this kind, however violent, falls far short of giving the stimulus imparted by a gentle breath. In removing specimens from one bottle to another I have often found a few of the less hungry ones disinclined to accept any opportunity to leave the bottom of the bottle. In such cases, when all other expedients failed to bring them out, I have found that breathing upon them soon induced them to come to the mouth of the bottle.

My observations on the habits of Clepsine marginata were made before my attention was directed to the question here considered; but, so far as my recollection serves me, I

should say that these Leeches are able to distinguish between a frog and a fish without being brought into contact with them.

This Clepsine is a fish parasite, and would be a favorable object with which to test this question.

I have made some experiments with one of our large pond Leeches (Macrobdella) for the purpose of ascertaining, if possible, the function, or functions, subserved by the different sense-organs. I have not been able to settle the main question, but the results are perhaps worthy of brief notice. The experiments were as follows:

1. The muddy bottom of a pool inhabited by these Leeches was shaken and stirred up by walking through it. This disturbance aroused the Leeches, and set them to swimming about in search of the intruder. I watched for any signs of method in their attempts to find me; and in various ways tried to find out if they were able to guide their course by a sense of sight, of smell, or of touch. The experiment was made in rubber-boots, on a bright sunny day; and, after starting the Leeches in the manner described, I remained quiet and observed the result. More than fifty Leeches made their appearance in the course of an hour. They swam about in all directions, the number coming towards me not exceeding those taking any other course. They sometimes halted, coming to rest on some plant, and then started up the moment the water was again disturbed. While on the move they generally kept at the surface, often throwing the head slightly above the surface; and when coming to rest they assumed an attitude, not of repose but of watchfulness, as if waiting for fresh evidence of my presence. I am not fully satisfied that their course was directed wholly at random, but I was unable to get any satisfactory evidence that they were able to orient themselves with reference to the place from which disturbing waves proceeded. Waves were made, by the hand or foot, to strike them from the side and from the rear; but they called forth no intelligent response, and only in comparatively few instances induced a change of course. The change of course in answer

to such stimuli, whenever it occurred, appeared to be made at random rather than with a definite aim. Several times I held the finger just in front and a little to one side of the head; but the Leech swam on without turning to grasp it, even when held so near that the margin of the body grazed it in passing.

2. Thirty to forty of these Leeches were captured and placed in a glass basin, and left until they had become quiet. Then the end of the finger was quietly rubbed over a small area on the bottom of the basin, care being taken not to arouse the Leeches by any sudden movement of the water. After withdrawing the finger, the basin was moved just enough to set the Leeches in motion. They began at once to search about, some swimming, others creeping, or stretching at full length and swinging from point to point. If the expanded lip chanced to rest for a moment on the spot which had been rubbed with the finger, the Leech instantly showed unmistakable evidence that it tasted or smelled something agreeable, and began to examine the place with that quick and excited movement of the head which it shows when brought into direct contact with the finger. This behaviour must, I believe, be attributed to a sense of taste rather than smell, since it is not called forth except by actual contact with the lip. In the course of a few minutes several Leeches found the spot, and felt it over with as much delight as if it had been the finger itself.

3. A drop of fresh blood was allowed to flow from a pipette over the dorsal surface of a Leech while in a state of repose. The Leech kept up a gentle undulating movement of the body, and gave no evidence of recognition. As soon, however, as the blood flowed over the margin of the lip the Leech became aware of its presence.

This experiment, repeated many times, appears to me to show that the eyes and segmental sense-organs of Macrobdella do not function as organs of taste or smell.

EXPLANATION OF PLATES XVII—XXI,

Illustrating Mr. Whitman's Paper on "The Leeches of Japan."

PLATE XVII.

FIGS. 1—9.—Hæmadipsa japonica and H. ceylanica.

FIGS. 1 and 2.—Dorsal and ventral view of H. japonica at rest. Natural size.

FIGS. 3 and 5.—Similar views of another individual in extension, showing a different colour. Natural size.

FIG. 4.—Dorsal view of another individual, partially filled with blood (in extension). Natural size.

FIG. 6.—The anterior end of Fig. 1, magnified 10 diameters, showing the position of the eyes and their serial homology with the median and lateral segmental papillæ.

FIG. 7.—The posterior end of the same individual, magnified 5 diameters.

FIGS. 8 and 9.—Dorsal and ventral view of H. ceylanica. Natural size.

PLATE XVIII.

FIGS. 10—20.—Hirudo nipponia.

FIG. 10.—An outline figure of the Leech represented in Fig. 18, showing the whole number of annuli, the arrangement of the eyes and segmental papillæ, the distribution of the dark pigment, the position of the first (13th annulus) and last pair (93rd annulus) of nephridial pores, and the position of the genital openings (between the 30th and 31st and the 35th and 36th annuli). × 2.

FIGS. 11—13.—Fig. 11 is a dorsal, and Fig. 13 a ventral view of a middle portion of the Leech represented entire in Fig. 12. Figs. 11 and 13 are magnified 4 diameters.

FIG. 14.—A much faded individual, in which the five stripes are only faintly indicated. Natural size.

FIG. 15.—A dorsal (*d.*) and a ventral (*v.*) view of two middle somites of a Leech from Aomori.

Fig. 16.—Similar views of another individual from the same locality, in which the lateral stripes are nearly obsolete.

Fig. 17.—A middle-sized individual from Tokio, in which the inner lateral yellow stripes have been replaced by black stripes, each of which represents two dark borders united.

Fig. 18.—An individual in which the yellow stripes have all been replaced by black stripes.

Fig. 19.—A typically coloured specimen.

Fig. 20.—An unusually dark variety, in which the yellow stripes are continuous, or nearly so.

PLATE XVIII.

Figs. 21—27.—Leptostoma pigrum.

Fig. 21.—An outline figure showing the whole number of annuli, the precise arrangement of the yellow pigment spots, the position of the genital pores, rings embraced in the clitellum, and the number of abbreviated somites—five at the anterior end, and three at the posterior end of the body.

Fig. 22.—The same coloured. Natural size.

Fig. 23.—Another individual, which shows the typical arrangement of the yellow spots in specimens found in the neighbourhood of Tokio.

Fig. 24.—Dorsal (*d.*) and ventral (*v.*) view of the Yezo type. Specimen obtained from a small lake (Junsainuma) near Hakodaté.

Fig. 25.—A Tokio pattern, in which the median spots are absent.

Fig. 26.—Another, in which the spots are all very small, the median ones being almost obliterated.

Fig. 27.—A dorsal and a ventral view, showing the position of the segmental papillæ and the nephridial pores. × 3.

PLATE XIX.

Figs. 28—39.—Leptostoma edentulum.

Fig. 28.—Dorsal view of a large individual, slightly extended.

Fig. 29.—Ventral side of the same.

Fig. 30.—Dorsal and ventral side of ten middle annuli. Five stripes present; the lateral stripes narrow, and brownish yellow.

Fig. 31.—Similar views of a specimen from Aomori.

Figs. 32, 33, 35, and 36.—Similar views of Tokio specimens, showing different shades and patterns.

FIG. 34.—A small individual found near Nikko. The median stripe is reddish brown, the lateral stripes are replaced with black. Transverse dark lines mark the limits of the somites.

FIGS. 37 and 39.—Two individuals from Tokio.

FIG. 38.—An enlarged view (× 2) showing the segmental papillæ of both sides, and the position of the nephridial pores.

PLATE XIX.

FIGS. 40—46.—Leptostoma acranulatum.

FIGS. 40, 43, 44, and 46.—Different patterns, taken from individuals found in Tokio. Natural size.

FIG. 41.—Dorsal side of ten annuli, enlarged (× 4) to show the segmental papillæ and the exact pattern of the colour-markings.

FIG. 42.—Ventral side of the same (× 4). The nephridial pores are about midway between the hind edge and the middle of the annulus.

FIG. 45.—Rudimentary denticles. × 165.

PLATE XX.

FIGS. 47—59.—Diagrams illustrating the abbreviated somites in several genera of Leeches. As it is one of the designs of these diagrams to show the topographical relations of parts and organs to the papillate annuli, it seems advantageous to regard the objects as transparent bodies, in which the genital pores, nephridial pores, &c., of the ventral side may be seen in relation with the papillæ of the dorsal side. Remembering that the figures are constructed on this plan, no confusion between dorsal and ventral organs need arise. The annuli are numbered on the right of the figures, the somites on the left. The nephridial pores are indicated by the ordinals, the first pair being denoted by 1*st p.*; the second, by 2*nd p.*; &c. *m.* Two median papillæ. *i. l.* Inner lateral papilla. *o. l.* Outer lateral papilla. *mg.* Marginal papilla. *p.* Nephridial pores (1st—17th). *g. c.* Glandulæ copulativæ. *m. o.* Male orifice. *f. o.* Female orifice. *b.* Black spots. *y.* Yellow spots. *l.* Lateral papilla of ventral side. × Magnified.

FIG. 47.—Anterior end of Hirudo medicinalis, from Sweden. × 2.

FIG. 48.—Two rings seen from ventral side, showing position of papillæ, pores, and distribution of the black pigment. × 2.

FIG. 49.—Posterior end of the same individual, showing a fragment only of the 102nd annulus. × 2.

FIG. 50.—Posterior end of H. medicinalis, obtained from Sebeto River.

Naples. The anus is in the 102nd annulus, nearly dividing this into two parts. × 2.

FIG. 51.—Aulostoma gulo, auct., from Sebeto River, Naples. In this specimen (alcoholic) the papillæ were very distinct, the full number appearing even on the 2nd annulus. × 4.

FIG. 52.—Aulostoma gulo obtained in Leipsic. The anus is large, completely cutting the two small rings of the 26th somite. × 4.

FIG. 53.—Leptostoma acranulatum, from Tokio. The 2nd annulus of the 23rd somite is thicker than the preceding annulus or the following, thus appearing to represent the two annuli fused together; in this particular it agrees with Macrobdella of America. The 105th annulus is a mere rudiment, and is somewhat doubtfully regarded as belonging to the body. × 4.

FIG. 54.—Leptostoma pigrum, from Japan, showing only five abbreviated somites. The last ring (10th) of the 5th somite represents two rings consolidated. The first pair of nephridial pores is in the hind edge of the 15th ring, instead of the 13th as in the European Leeches. The arrangement of the stripes and spots, and the relation of the segmental papillæ to the stripes, are also shown. × 4.

FIG. 55.—The hind end of the same Leech, showing one full somite and three abridged somites behind the 17th pair of nephridial pores. The 106th annulus is completely cut by the anus. No marginal papillæ were visible. × 4.

FIG. 56.—Hirudinaria javanica.—(Hirudo javanica, Wahlberg), showing very large segmental papillæ with a definite inclination, which is repeated on every papillate ring. Their arrangement on the acetabulum shows that the eight or more somites, of which it is composed, are each represented by the papillate ring alone, all the non-papillate rings having been suppressed. The figure shows one of the ventral papillæ (*mg'*). The 102nd annulus forms a sort of neutral ground between the body and the acetabulum, and consists of two halves separated by the anus. The acetabulum is immense, reaching forward to the level of the last pair of nephridial pores (17th p.). × 4.

FIG. 57.—Macrobdella sestertia, obtained from Charles River, Watertown, Mass., shows the dorsal surface of the first twelve somites, and the position occupied by the organs of the ventral surface (nephridial pores, genital pores, and copulatory glands) (*gc.*). × 4.

FIG. 58.—Eleven rings seen from the ventral side, to show the position of the papillæ and the pores. The lateral papillæ (*l.*) are in line with the nephridial pores (*p.*). × 4.

FIG. 59.—The posterior end of M. sestertia, showing an abbreviation similar to that seen in Fig. 53 (Leptostoma acranulatum). × 4.

PLATE XXI.

FIGS. 60—71.—Reproductive Organs and Maxillæ.

FIG. 60.—Median dorsal maxilla of Hirudinaria javanica, seen in profile. There are from 115 to 120 denticles decreasing gradually in size from the inner (inferior in the natural position) angle (*i.*) towards the external (superior) angle (*e.*). The maxilla is thicker than the fold (*f.*), to which it belongs; and its inner angle rises abruptly above the level of the fold. Rather large wart-like protuberances are seen on the lateral faces of the maxilla. × 50.

FIG. 61.—One of the maxillæ of Leptostoma pigrum, showing no denticles, but only two series of irregular flattened plates, which are more or less united, especially at the two angles (*i.* and *e.*) where they bend into each other, thus completing the circuit of the outer edge of the jaw. These chitinous plates rest on a thick muscular welt (*w.*). × 130.

FIG. 62.—An outline of the face of the jaw, showing that the plates are continuous, but weakly developed at the two angles (*i.* and *e.*). Numerous small irregular chitinous pieces are scattered throughout the area inclosed by the larger plates. × 130.

FIG. 63.—A profile view of the maxilla of Leptostoma edentulum. The jaw here is so small that it scarcely deserves the name; it is the anterior end of the fold (*f.*) slightly enlarged, and has no denticles nor any traces of even rudimentary plates. × 50.

FIG. 64.—Reproductive organs of Leptostoma acranulatum. The male organ opens between the 6th and 7th ganglia (counting the sub-œsophageal as one); the female organ between the 7th and 8th. The ovaries have shifted their position from between the 7th and 8th ganglia to a point just in front of the 12th ganglion. The vagina and penial pouch are extremely long. × 4. *t.* Testis. *vd.* Vas deferens commune. *vs.* Vesicula seminalis (epididymis). *d.* ductus ejaculatorius. *gp.* Glandulæ prostaticæ *p.* Penial pouch (sacculus penis). *o.* Ovaries. *gl. alb.* Glandulæ albuminiferæ. *od.* Oviduct. *od. c.* Oviductus communis. *v.* Vagina.

FIG. 65.—Female organs of Hirudo nipponia. Letters as before. × 4.

FIG. 66.—Female organs of Leptostoma edentulum. × 4.

FIG. 67.—Female organs of Leptostoma pigrum. The vagina differentiated into a tubular and a saccular portion. The common oviduct. (*od. c.*) adheres closely with the saccular portion of the vagina. × 4.

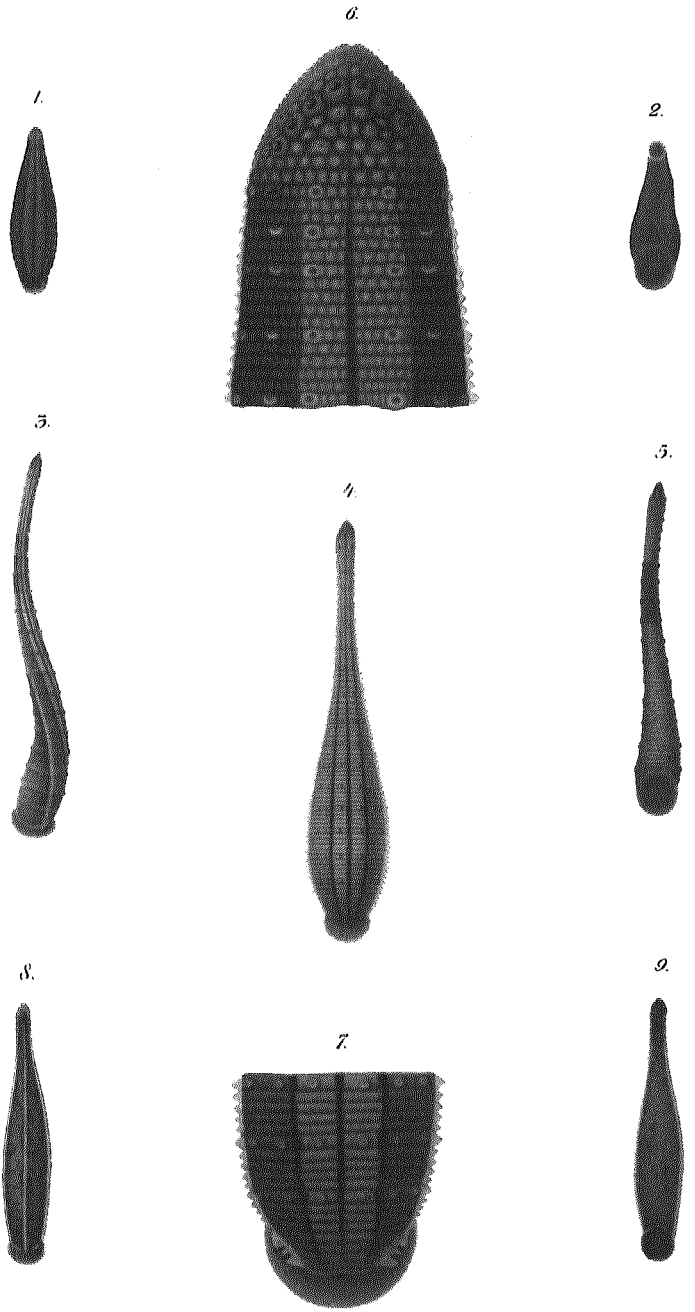
FIG. 68.—Female organs of Hæmadipsa japonica. Here the com-

mon oviduct has united with the saccular portion of the vagina, and thus appears to enter its anterior instead of its posterior end. × 4.

FIG. 69.—A maxilla armed with curved denticles, from Hæmadipsa japonica. × 50.

FIG. 70.—A maxilla with straight conical denticles, from Hirudo nipponia.

FIG. 71.—Two of the large central cells of the eye (Macrobdella). *n*. Nucleus. 1, 2, 3. Vacuolar spaces surrounded by the peripheral granular protoplasm. At one point the protoplasm thickens into a protuberance, which juts into the vacuolar space. × 465.



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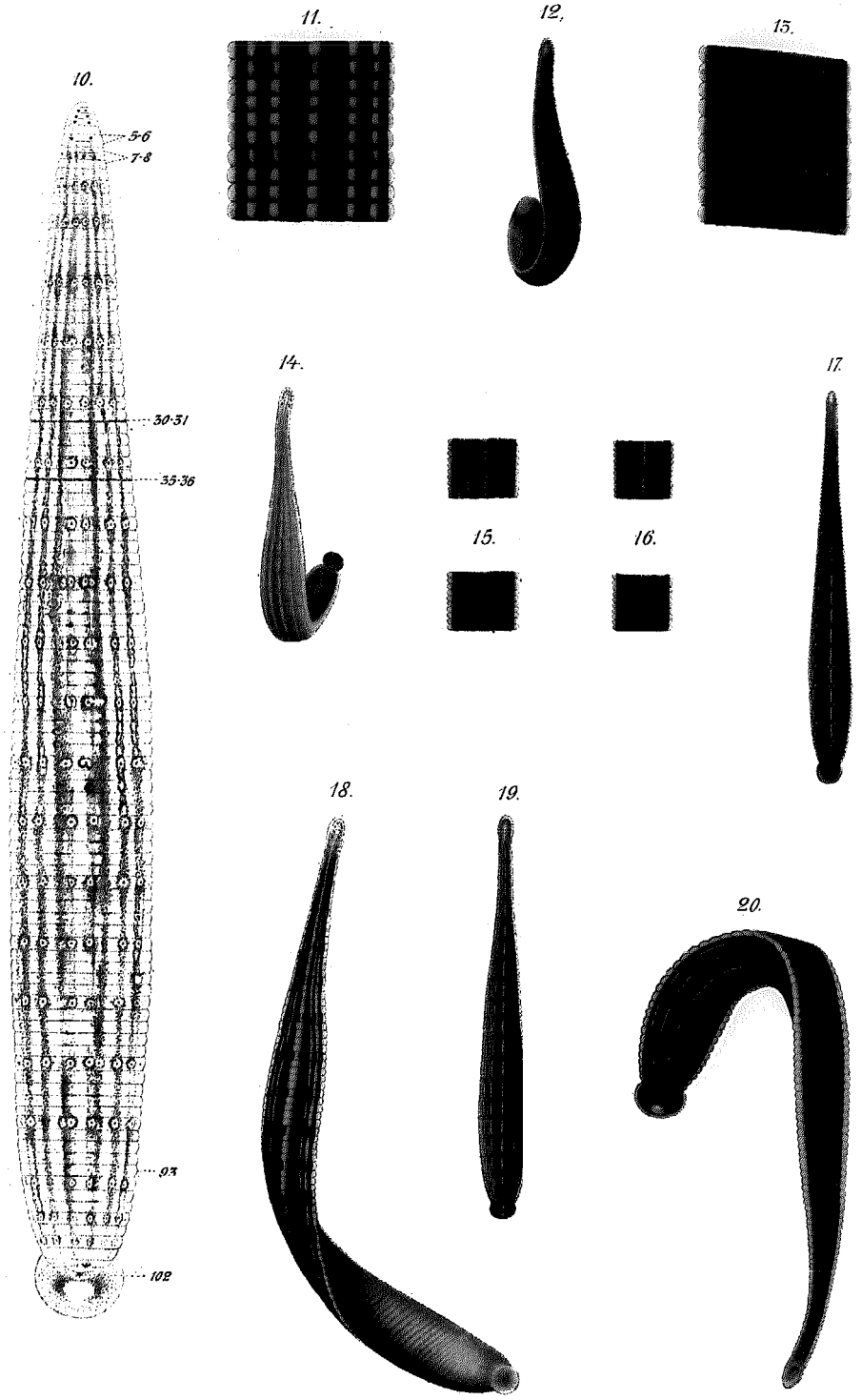

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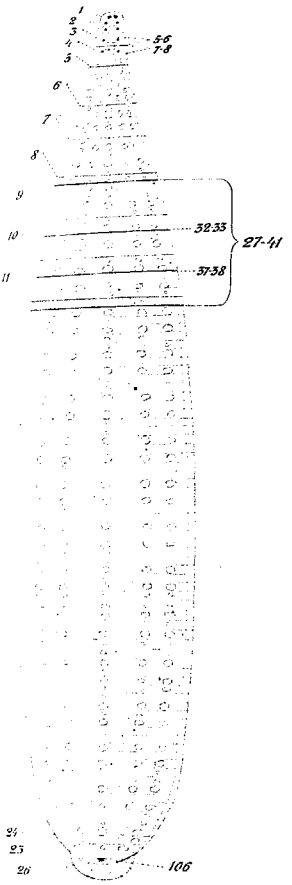

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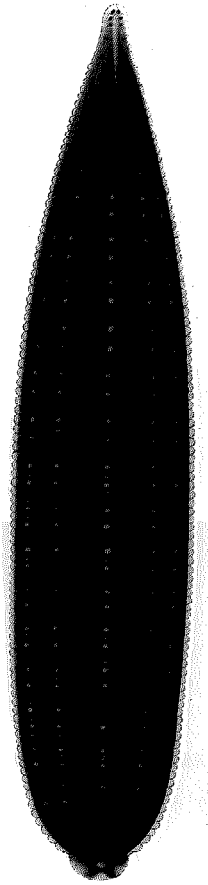

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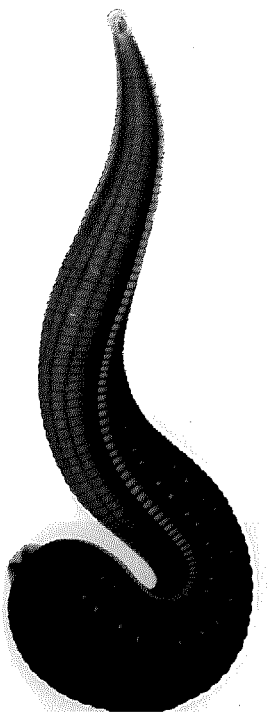

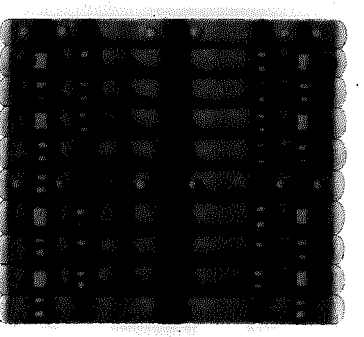

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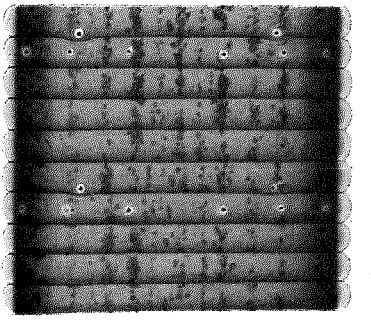

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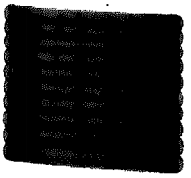

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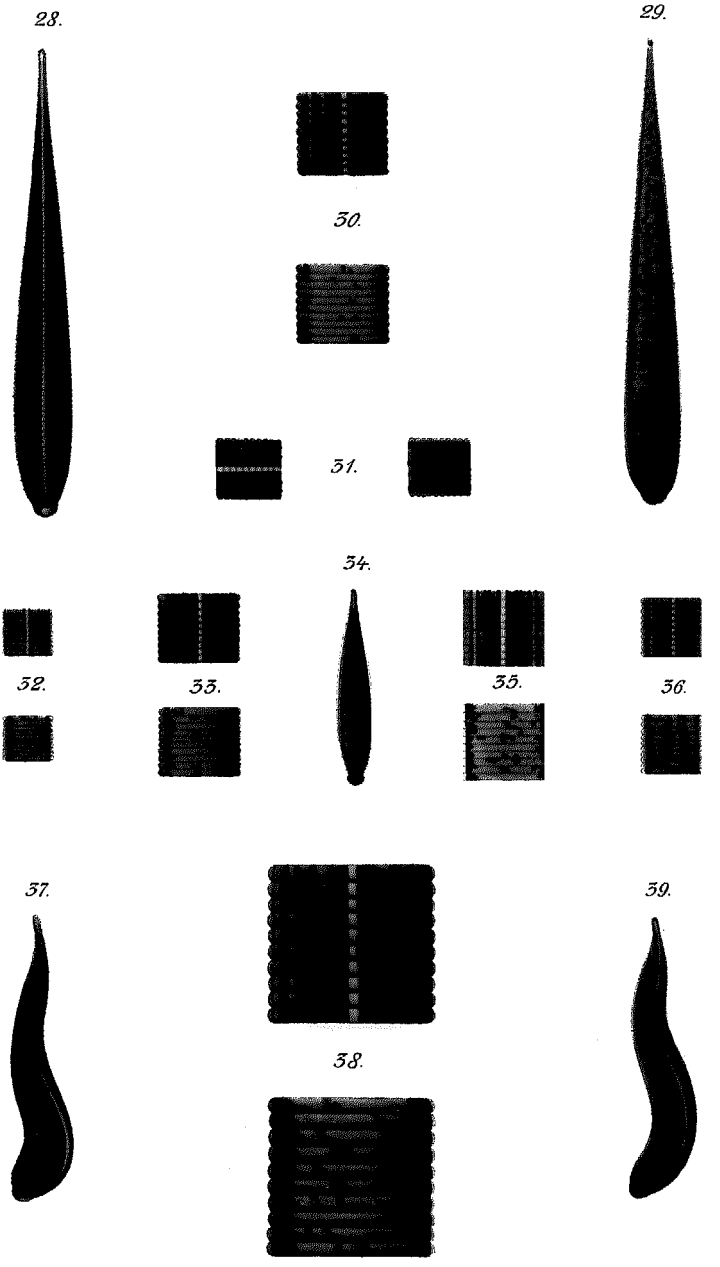

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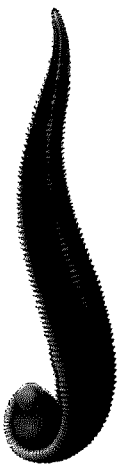

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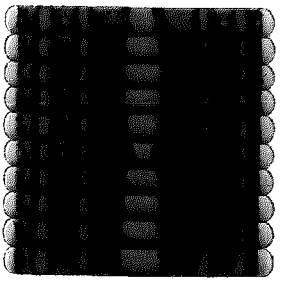

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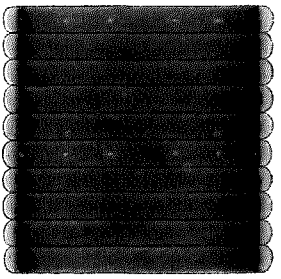

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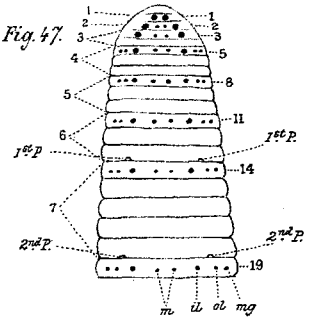

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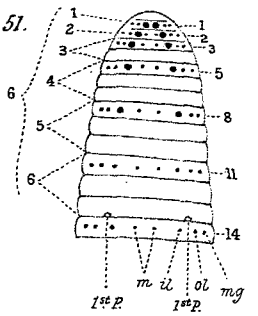

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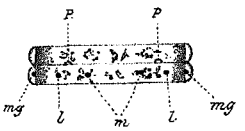

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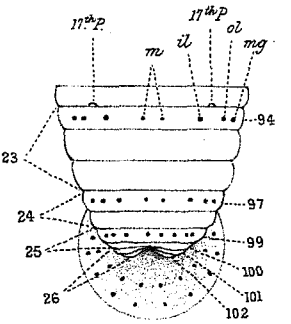

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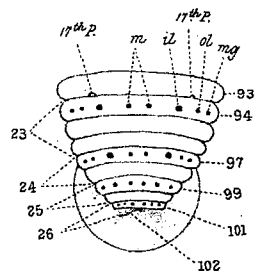

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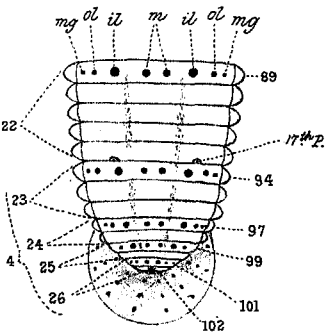

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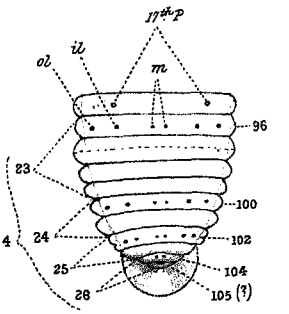

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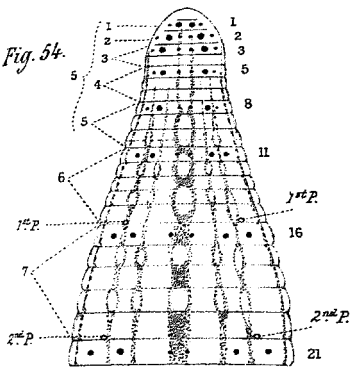

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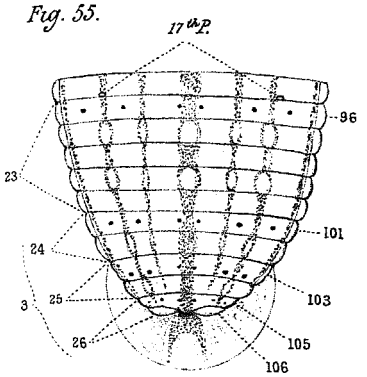

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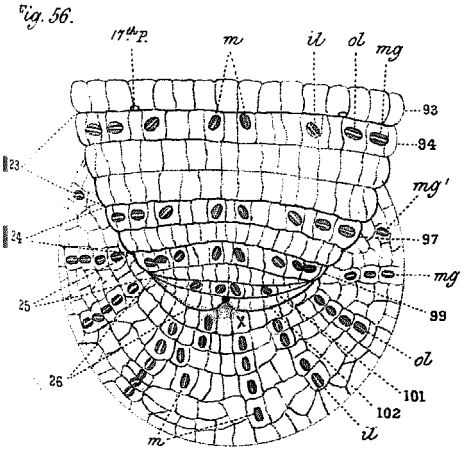

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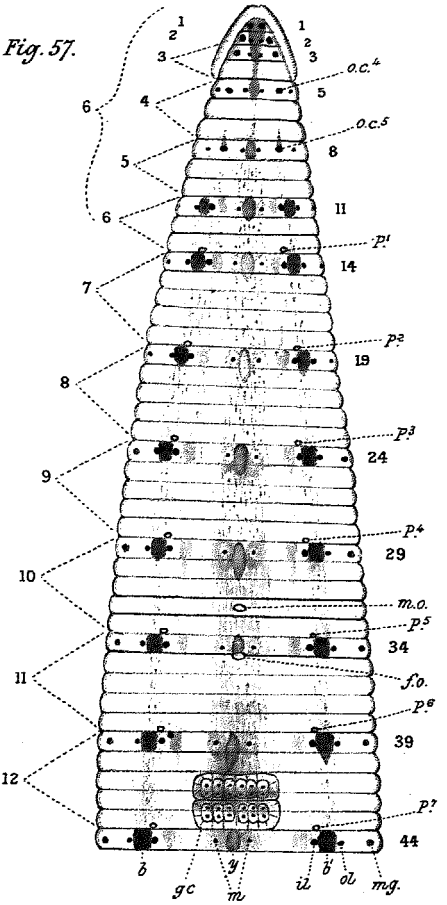

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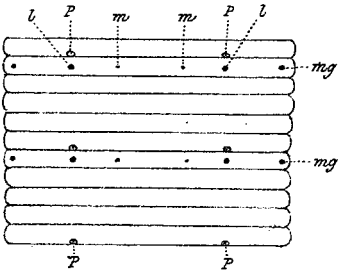

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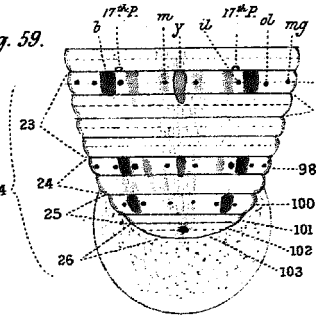

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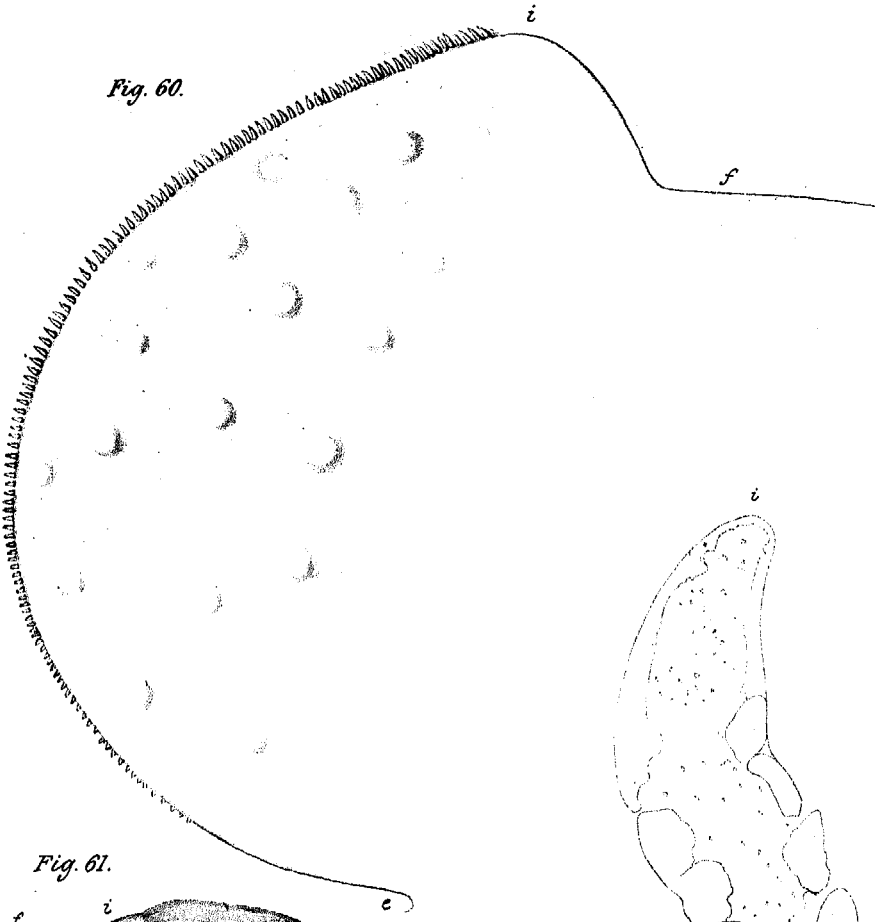

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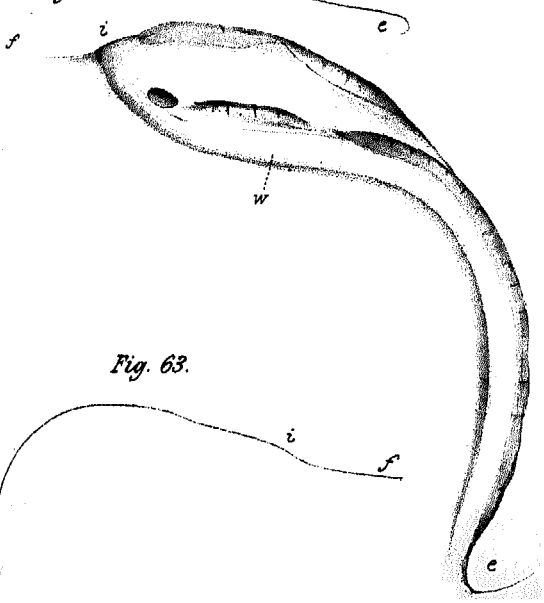

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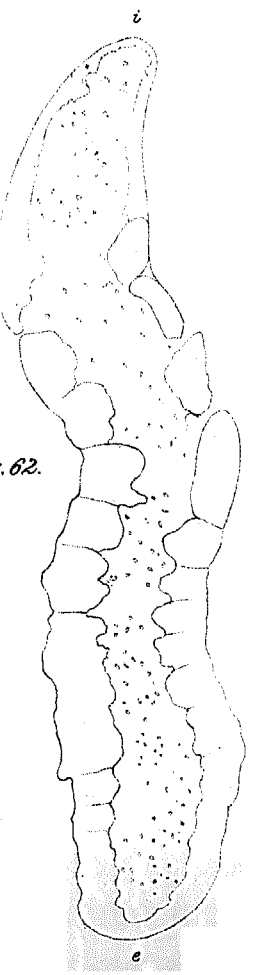

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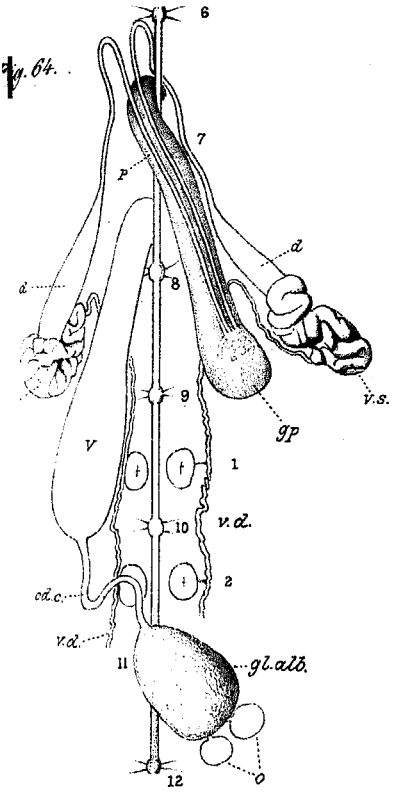

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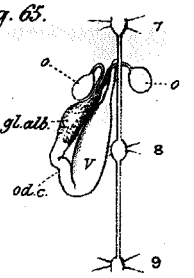

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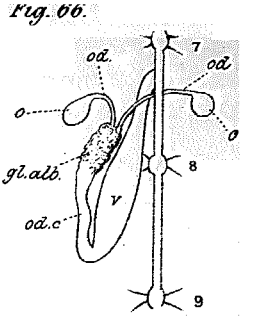

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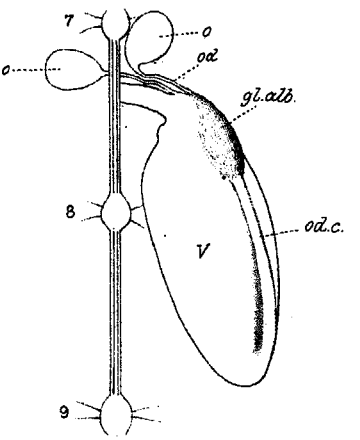

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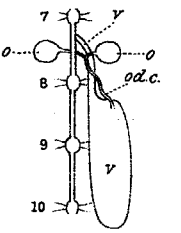

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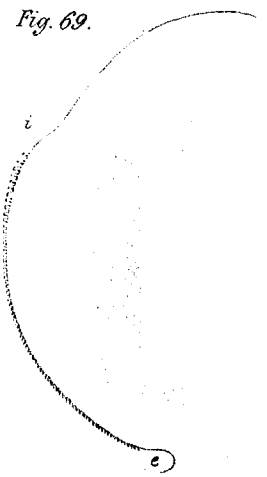

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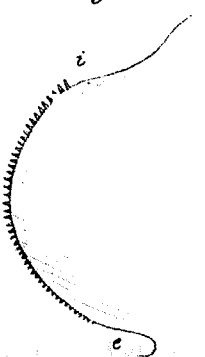

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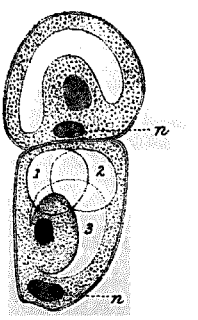

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