V. *On the Anatomy and Histology of the Land-Planarians of Ceylon, with some Account of their Habits, and a Description of two new Species, and with Notes on the Anatomy of some European Aquatic Species.* *By* H. N. Moseley, *M.A. Oxon. Communicated by* G. Rolleston, *M.D., Professor of Anatomy and Physiology in the University of Oxford.*

Received January 16,—Read February 20, 1873.

Preface.

At the outset I would desire to express my deep obligations to Professor Rolleston in the matter of this paper. I was first informed of the existence of Land-Planarians in Ceylon by Professor Rolleston, and of the importance of investigating the correctness or incorrectness of Schmarda's description of a ganglionated nerve-cord in *Sphyrocephalus*, to which Professor Rolleston has referred in his 'Forms of Animal Life,' as have also many other authors. Professor Rolleston at first agreed that the paper should be a joint one, and himself prepared a large number of sections of *Rhynchodemus*, one of which is figured, but subsequently decided that my name only should appear in the matter. I have to thank him for suggestions and assistance rendered during the whole of the investigation, which took more than two months' constant work, and also for help in the getting up of the bibliography of the subject. The work was done in the Anatomical Department of the Oxford Museum.

The Land-Planarians the anatomy and histology of which are described in the present memoir were obtained in Ceylon during the months of January and February last year (1872) by the author, in the Royal Botanic Gardens, Peradeniya, Ceylon, through the kind assistance of G. H. K. Thwaites, Esq., F.R.S., the distinguished Curator of those Gardens.

The Planarians are forms of very great interest, as lying in the stem of the family-tree of the animal kingdom at a point where very many branches are given off by it. *Bipalium* and *Rhynchodemus*, as being the largest of known Planarians, offer especial advantages for an accurate and complete investigation of their anatomy; and a thorough knowledge of the anatomy of these larger forms cannot fail to throw great light on that of their smaller congeners. It is also of extreme interest to see how far largeness of size and difference of habit is accompanied by corresponding modifications of structure in forms such as these. The published accounts of the anatomy of *Bipalium* and *Rhynchodemus* are, as will be seen in the sequel, imperfect and, in many very important particulars,

erroneous. On the whole, then, no apology is required for the present memoir. A list of all the works referred to is given further on; when more than one memoir by the same author is cited the successive memoirs are numbered.

Land-Planarians were first discovered by O. F. Müller in Denmark in 1773 (*loc. cit.** *infrà* 1, p. 68), and the species he discovered was called by him *Fasciola terrestris*. Dugès discovered the same species in Languedoc in 1830 (*loc. cit.* 2), and called it *Planaria terrestris*; Fritz Müller discovered it at Greifswald in Germany; Noll found it in Switzerland, at St. Goar, in 1862 (*loc. cit.*); Grube in Silesia in 1866 (*loc. cit.*). It was first discovered in England by Mr. Jenyns (Observations in Nat. Hist. p. 315, 1846) at Bottisham Hall; then by Sir John Lubbock, Bart., in Kent (*loc. cit.*), in 1868; and, thirdly, by the Rev. W. Houghton, M.A., F.L.S., in Shropshire. During this period and subsequently a large number of Land-Planarians have been discovered in various parts of the world, and have been referred to several genera, and indeed to different families.

All the Land-Planarians as yet known belong to the Dendrocœlous group of these animals, which group is thus split up by Diesing (*loc. cit.*), here quoted only as far as regards Land-Planarians:—

Dendrocœla.

Family I. Planaridea (eyes two).
. . . . Genus *Rhynchodemus*.

Family II. Polycelidea (eyes many).
Phalanx I. *Polycelidea apoda*.
Phalanx II. *Polycelidea gasteropoda*.
Subfamily III. *Geoplanidea*.
Genera. *Geoplana*.
Bipalium.

The genus *Rhynchodemus* is thus characterized† by its founder; and under this genus are included by Diesing the following Land-Planarians:—

Rhynchodemus	Denmark. O. F. Müller.
	England. Sir J. Lubbock (Kent), 1868; Houghton (Shrops.), Ann. & Mag. 1870, vi. p. 256; and first by Jenyns, Observations in Nat. Hist. p. 315.
terrestris	France. Dugès, 1830.
	Germany, Greifswald. Fritz Müller.
	Germany, Silesia. Grube, 1866.
	Switzerland, St. Goar. Noll, 1862.

* See pp. 113–115 *infrà* for Bibliography.

† "Corpus elongatum, subdepressum, antrorsum attenuatum, utrinque obtusum. Ocelli duo subterminales." —Dr. Leidy, Proc. Acad. Nat. Sci. Philad. vol. v. 1851.

Rhynchodemus *sylvaticus*	N. America. Leidy, Proc. Acad. Phil. 1851, pp. 241, 289; 1858, p. 172. Said by Schmarda (Neue wirbellose Thiere, 1859) to be very like *terrestris*.
bistriatus, *quadristriatus*	Samoan Islands (Navigator Islands, Schiffer-Inseln). Grube.
Nietneri	Ceylon. Humbert, Mém. Soc. Phys. Genève, 1861, p. 306.

And there may now be added

tannagi	Brazil. Férussac, Ann. Gén. Sci. Phys. vol. viii. 1821, pp. 90–92.
bilineatus (*Geodesmus*)	Giessen? Mecznikow, Bull. Acad. St. Pétersb. 1865, vol. ix. p. 433.
Thwaitesii	Ceylon. *Mihi*, 1872.

In the absence of any accurate description of the anatomy of most of the animals included under this genus *Rhynchodemus*, the genus cannot yet be said to be very satisfactory. Observations on the anatomy of *R. terrestris* and *R. sylvaticus* are very much wanted. It is uncertain whether Mecznikow's *Geodesmus*, which, as Grube (Jahresbericht, *loc. cit.* p. 64) remarks, was probably not European, but introduced with foreign plants, should be considered a *Rhynchodemus* on account of its elongated body and single pair of eyes. At all events, as far as *R. Thwaitesii* and therefore *R. Nietneri* (which is evidently closely allied) are concerned, Diesing's wide separation of the genera *Rhynchodemus* and *Bipalium* is unfortunate. The two genera are evidently closely allied in the presence in both of an ambulacral line, the absence of ramifications on the inner side of the posterior prolongation of the digestive tract, and in the arrangement of the muscular structures and viscera, as also in general facies, colouring, and habit. Stimpson (*loc. cit.* 1) is quite right in placing together the genera *Geoplana*, *Bipalium*, and *Rhynchodemus*; but in his description of the subfamily the statement concerning the mouth will not apply to that of *Rhynchodemus*, and the discovery of eyes all down the body of *Bipalium* necessitates a further change in the definitions given both by Diesing and Stimpson.

Altering slightly from Stimpson (*loc. cit.* 1, p. 24), the definition of the subfamily Geoplanidæ will stand thus:—

Geoplanidæ.—Corpus elongatum depressum vel depressiusculum subtus pede sat distincto; caput continuum vel discretum. Ocelli duo vel plurimi in capite solum aut etiam passim in corpore dispositi. Os postmediale. Œsophagus protractilis campanulatus margine sæpius sinuoso aut doliiformis. Apertura genitalis pone os.

Under this subfamily there stand the three genera *Geoplana*, *Bipalium*, and *Rhynchodemus*. The genus *Bipalium* was formed by Stimpson (*loc. cit.*) to include four species of remarkable Land-Planarians which he obtained on the U. S. A. Expedition under Captain Rodgers. The genus is an extremely well-marked one, being distinguished by

the extraordinary cheese-knife-shaped anterior extremity or head. The following is Stimpson's diagnosis of the genus with the slight alteration concerning the eyes:—Corpus lineare, depressiusculum; caput discretum lunatum transversum, auriculis longis retrorsum tendentibus. Ocelli numerosi, minuti, in capite plerumque in ejus marginibus, et etiam nonnunquam in corpore usque ad extremitatem posteriorem sparsim dispositi. Os centrale vel postcentrale. Apertura genitalis inter os et extremitatem posteriorem, sæpius ad dimidiam distantiam.

The first to describe a species of this genus was Dr. Gray, of the British Museum, who in 1835 named a *Bipalium* from Bengal *Planaria lunata*. Cantor next (in 1835) evidently speaks of a *Bipalium* as occurring in China, but he does not name the animal. The Rev. W. Houghton, M.A., F.L.S. (*loc. cit.*), describes and figures two Land-Planarians from Borneo, the shapes of the heads of which evidently show them to belong to the genus *Bipalium*. As he gives no name to them, I propose to call No. 1 *Bipalium Everetti*, after Mr. Alfred Everett, who discovered them in Borneo, and the other *B. Houghtoni*.

The following is as perfect a list as I have been able to form of the species of *Bipalium* at present known to exist:—

Bipalium

Phœbe	Ceylon.	Humbert, Mém. Soc. Phys. Gen. 1861, p. 302.
Diana		
Proserpina		
Ceres	Ceylon.	*Mihi*, 1871–72.
dendrophilus . . .	Ceylon.	Schmarda, Neue wirbellose Thiere, 1859, p. 36.
lunata	Bengal.	Gray, Zool. Misc. p. 5, 1835, cit. Silliman's Journ. 1861, p. 135.
ferudpoorensis . . .	Bengal.	Wright, Ann. & Mag. Nat. Hist. 1860, vi. p. 54; see also Cantor, Naga Hills.
„ ? . . .	Naga Hills.	Ann. & Mag. Nat. Hist. 1842, ix. p. 277.
Cantoria	China.	
Grayia	Chusan.	
Stimpsoni	China, Hong Kong.	See Silliman's Journal, 1861, pp. 134 & 135.
virgatum	Loochoo.	U. S. A. Expedition under Captain Rodgers. Stimpson's Prodromus, Proc. Acad. Philad. 1857, pp. 30, 31.
maculatum	Ousimon.	
fuscatum	Simodu.	
trilineatum	Jesso.	
	Madras.	Novara Exped. Band ii. Abth. 3, p. 45. Grube.
Everetti	Borneo.	Rev. W. Houghton, M.A., F.L.S., Ann. & Mag. Nat. Hist. 1870, vi. p. 255.
Houghtoni	Borneo.	Rev. W. Houghton, M.A., F.L.S., *ibid.*

Professor SEMPER, of Würzburg, has told me that he has a number of species of Land-Planarians to describe from the Philippines. No doubt some of these will belong to our present genus. The species referred to by Dr. CANTOR as having been found under stones in the Naga Hills by Mr. GRIFFITH in 1836 may possibly be the same as the species from Ferudpoor described by Dr. PERCEVAL WRIGHT in 1860 (*loc. cit.* p. 54), the two localities being at no very great distance apart. It is also possible that *B. Cantoria*, discovered by Mr. FORTUNE in China, may be the same as *B. Stimpsoni* discovered by Sir J. BOWRING in Hong Kong.

A map may readily be made to show the distribution of the genus *Bipalium*, in a manner which cannot fail to be of interest in the case of a genus so well marked as this. The range will be seen to be a wide one, extending from Jesso to Ceylon, but still to be much more confined than that of either *Rhynchodemus* or *Geoplana*. GRUBE (*loc. cit.*) remarks that the Land-Planarians correspond in their distribution with the Land-Leeches, in so far as neither animals are found in Western Asia or Africa.

Mr. LAYARD noticed his specimens at St. Pedra. In Ceylon itself the genus *Bipalium* seems to be widely spread. HUMBERT found his specimens at Kandy, and also *Rhynchodemus*, on a coffee-estate further up amongst the hills. SCHMARDA found his at Bellingham; and I obtained one specimen at Trincomalee like *B. Proserpina*, but it unfortunately perished.

Of the genus *Geoplana* twenty-one species are enumerated by DIESING (Akad. Wiss. Wien, 1861, pp. 509, 513). These species have been observed by DARWIN, FR. MÜLLER (Halle Abhandlung. *loc. cit.* p. 25), DIESING (Sitz. Akad. Wiss. Wien, *loc. cit.* p. 496), *Polycladus*, in the Andes, DIESING (*loc. cit.* p. 495), SCHMARDA (Neue wirb. Thiere, Taf. ii. fig. 31), and *Limacopsis*, DIESING (*loc. cit.* p. 519), SCHMARDA (*loc. cit.* Taf. vi. fig. 69).

The Land-Planarians of Ceylon were first observed by Mr. LAYARD (*loc. cit.*); but he mistook the anterior extremity of the animal for its tail, and did not name the species. SCHMARDA (*loc. cit.* p. 36) describes a *Bipalium* from Ceylon, but being apparently unacquainted with STIMPSON'S genus, makes a genus *Sphyrocephalus* for it. He figures his species (Taf. viii. fig. 83, Band i.) under the name of *Sphyrocephalus dendrophilus*. ALOIS HUMBERT (*loc. cit.*) describes three new species of *Bipalium* from Ceylon, and gives beautiful figures of them drawn from life; he names them *B. Diana*, *Proserpina*, and *Phœbe*. Another Planarian which he obtained he refers to the genus *Rhynchodemus*, *R. Nietneri*. I obtained abundance of specimens of *B. Diana* and *B. Proserpina*, but none of *B. Phœbe* or *B. Nietneri*; but I found a new species of *Bipalium*, and also a new *Rhynchodemus*.

The following are the characteristics of the new species of *Bipalium*:—

B. Ceres, Plate X. figs. 1 & 2. Body rather more convex superiorly, and less broad in proportion to its length, than in the other Ceylon species. Upper or dorsal surface divisible into five bands or stripes, a median and two pair of lateral. The median is light yellow in colour; the two bands which lie on either side of it are pale brownish and of little more than linear width. The external lateral bands are in every part of

the animal's length of at least the width of the central one, from which they differ by being of a slightly browner yellow colour. The whole of the animal's dorsal aspect is irregularly dotted with black specks. The semicircular anterior border of the head is limited by a dark violet line, immediately anterior to which a broader but similarly semilunar band of flesh-colour is to be seen on the dorsal surface. The central dorsal band is in some specimens prolonged up so as to join this band; in others it falls short of this; in all it swells out into a sort of lozenge-shaped termination, sharply defined on each side by a dark violet patch, which shades off gradually into the dusky yellow of the lateral bands of the body. On the under surface of the body, on each side where the convex surface of the dorsal aspect meets the nearly flat ambulacral surface, a *slight ridge* is formed extending the whole length of the body. This ridge is highly characteristic of this species, and contains peculiar glandular bodies not present in the other two species of *Bipalium* examined.

Dimensions of an average specimen after contraction in spirit:—

	millims.
From anterior extremity to mouth	52
From mouth to generative orifice	12
From generative orifice to posterior extremity	15
Entire length . . .	79

Habitat. The Royal Botanic Gardens, Peradeniya, Ceylon, in company with *B. Proserpina* and *B. Diana.*

The possession of a large series of specimens allowed the difference between young animals and adults to be studied. In *Bipalium Ceres* and also *B. Diana* the very young specimens are much more definitely marked than the adults. The animals gradually lose their definite striping as they grow older. The case is paralleled in many instances amongst higher animals. It would appear here as if the species were endeavouring to escape detection by enemies by getting rid of a somewhat conspicuous colouring which at present survives only in the young condition.

Fig. 2, Plate X., represents a very young specimen of *B. Ceres.* The lateral bands are in young specimens much browner, and the central band of a brighter yellow; the two linear intermediate stripes are jet-black.

Fig. 3, Plate X., shows a very young specimen of *B. Diana.* A comparison of this drawing only with that of M. Humbert's of the entire animal would lead to the conclusion that the present must belong to another species, but the examination of a large series of specimens has shown that this is undoubtedly the young of *B. Diana.* A very narrow light-coloured line is seen in the midst of the broad black line on the head, and this light-coloured line extends a short distance along the animal's back; it represents the broad median light-coloured line of *B. Ceres*, and shows *B. Diana* to be five-striped in the early condition, as are nearly all the Ceylon Land-Planarians. The longest specimen of *B. Diana* obtained measured $5\frac{1}{2}$ inches in length and $\frac{1}{4}$ inch in breadth; it was used for

dissection. *B. Proserpina* in the young condition is marked exactly like the adults of the same species, but in this case the adults are conspicuously banded.

The following are the characteristics of a new species of *Rhynchodemus*. In ascribing the species to the genus *Rhynchodemus* I have followed M. HUMBERT, this animal being evidently of the same genus as his *R. Nietneri*.

Rhynchodemus Thwaitesii, sp. nov., Plate X. fig. 4. The dorsal surface of the animal may be considered divisible into three bands, a median and two lateral, of about equal width: the median band light brownish yellow with a black line down its centre; the two lateral bands violet-grey, very dark at the edges which bound the median band, but shading off into a light tint at their outer margin. The animal is thus five-striped. Ventral surface marked by a median white band, the ambulacral line bordered by darkish violet-grey.

Dimensions of an average specimen after contraction in spirit:—

	millims.
From tip of tail to generative orifice	10
From generative orifice to mouth	12
From mouth to tip of anterior extremity	22
Entire length . . .	44

Habitat. The Royal Botanic Gardens, Peradeniya, Ceylon, occurring, together with three species of *Bipalium*, amongst fallen leaves &c. in plantations, especially abundant in Banana and Manilla-hemp plantations. The species I have named after my friend Mr. G. H. K. THWAITES, F.R.S., the distinguished Curator of the Peradeniya Gardens.

On the Habits of Land-Planarians.

Land-Planarians are probably all of them nocturnal in habit. DARWIN (*loc. cit.* p. 249) remarks on the avoidance of light by *Geoplana*, and Dr. LEIDY (*loc. cit.* 2, p. 172) observed *Rhynchodemus sylvaticus* to be a nocturnal animal crawling about on fences at night. *Geoplana subterranea* (*Geobia*, DIESING), according to F. MÜLLER, lives underground in the holes of *Lumbricus corethrurus* (Halle Abh. *loc. cit.* pp. 26, 27). The Ceylon Land-Planarians appear to avoid light in the same manner as the *Geoplanæ*; they are to be found in dark places, such as under large fallen leaves, and in confinement they coil themselves up away from the light.

This avoidance of light appears to be common to nearly all Planarians, and not confined to terrestrial forms. MAX SCHULTZE (*loc. cit.* 1, p. 17) refers to the fact that aquatic Planarians always choose the darkest side of any vessel in which they may be placed to rest upon; and I have myself observed this fact in the case of *Planaria torva* and *Dendrocœlum lacteum*. Green chlorophyl-containing Planarians, such as *Mesostomum viridatum*, form an exception to the general rule, since, as MAX SCHULTZE informs us (*loc. cit.* 1, p. 17), they always place themselves on the light side of a vessel: they nevertheless die when exposed to direct sunlight. It may have been due to the fact that I did not give them sufficient shade that all my attempts to keep the Ceylon Land-

Planarians alive in confinement failed. I never preserved them for more than a few days. Mr. THWAITES, who has also tried the experiment several times, has had a like result. Mr. DARWIN seems to have found no difficulty in keeping *Geoplanæ* alive: he kept some alive in a box twenty-one days, and they increased in size during that time.

The Planarians which I obtained were almost all procured in a Manilla-hemp plantation in the Royal Botanic Gardens, Peradeniya, Ceylon, under fallen leaves and under the leaf-sheathes of the growing plants. I found some in these situations myself; but the larger number were procured by one of Mr. THWAITES's coolies, trained by him as a collector. The coolie's plan was to lay a large fresh plantain-leaf on the grass near the plantation, and in a few hours he found the Planarians adhering to the under surface. Three species of *Bipalium* and one of *Rhynchodemus* were obtained all together in this manner. Occurring with the Planarians is found, as remarked by M. HUMBERT (*loc. cit.* pp. 302–3), the mollusk *Vaginulus*, which was also found associated with *Geoplana* in South America by Mr. DARWIN (*loc. cit.* p. 241). Mr. DARWIN was led to believe that *Geoplana* fed on rotten wood; but this is most probably not the case. All Planarians appear to be carnivorous, like their congeners the Nemertines (M'INTOSH, *loc. cit.* p. 338); and it is possible that the increase in size observed in his specimens by Mr. DARWIN was due to cannibalism on their part. MAX SCHULTZE searched carefully in the digestive tract of *Geoplana* (Halle Abhandl. *loc. cit.*) and found no trace of vegetable tissue in it; but he did find the palate and jaws of a snail.

FR. MÜLLER (Halle Abhandl. *loc. cit.* p. 27) says that *Geobia* sucks out the juices of its host *Lumbricus corethrurus*. LEIDY (Proc. Acad. Sci. Phil. 1858, p. 172) fed *Rhynchodemus sylvaticus* with crushed house-flies; and although I have examined microscopically sections of twenty or thirty individuals of four species of Ceylon Land-Planarians, I have never seen a trace of vegetable tissue in their intestines. As far as regards aquatic Planarians, Von BAER, who was the first to give an account of the anatomy of Planarians and separate them from the Leeches, with which they had been confounded by SHAW and KIRBY long ago, remarked (Nova Acta, tom. xiii.) on the carnivorous propensities of these animals; and on Professor ROLLESTON placing an earthworm, killed by immersion in warm water, in a dish in which were a number of living *Planariæ torvæ* and *Dendrocœla lactea*, these animals crowded on to the worm's body and soon sucked all the hæmoglobin out of it, leaving it white and pulpy.

Dr. LEIDY remarked that from the tail end of *Rhynchodemus sylvaticus* is secreted a delicate mucous thread; and Sir J. DALYELL (*loc. cit.* vol. ii. p. 113) observed of *Planaria Arethusa* that it makes threads of mucus, by means of which it suspends itself in the water. *Bipalium* in the same manner uses a thread of its tough investing slime for suspension in air; and I have frequently seen it let itself down in this manner from a twig held at a short distance from the ground. The cellar-slug makes use of a slime-thread for suspension in the same manner. This fact in the habits of *Bipalium* does not seem to have been noticed by M. HUMBERT, although he gives a very interesting account of that animal's mode of life in his memoir (Mém. Soc. Phys. de Genève, xvi.

1861, p. 294). *Bipalium*, as is observed by this author, when moving carries its head slightly elevated, and moves it from side to side, evidently investigating with it any obstacles which occur in the line of movement. When the semilunar head is thus made use of, there are projected from its narrow anterior border tentacular-like eminences, which appear to be used as feelers. The tentacles are evidently not localized, but may be formed at any spot on the border of the head by contraction of surrounding tissue. M. HUMBERT searched for some corresponding permanent papillæ or sense-organs on the border of the head without success; but I have been more fortunate, and have found a peculiar narrow line of delicate papillæ in this region, evidently connected with the sensory function of this part of the head, and which will be described in the sequel. See Plate XIII. figs. 16 & 17, and their accomanying descriptions.

The following is a list of the works and memoirs concerning Planarians and allied forms which have been consulted, and to which reference is made in the present paper.

PALLAS ..... Spicilegia Zoologica, Hft. 10. 1774.

O. F. MÜLLER ..... 1. Vermium terrestrium et fluviatilium, seu Animalium Infusoriorum, Helminthicorum, et Testaceorum, non marinorum, succincta historia. Hafniæ et Lipsiæ, 2 vols. 4to, 1773–74.

2. Zoologiæ Danicæ Prodromus, ii. p. 698. 1776.

3. Zoologia Danica, vol. iii. p. 49. 1789.

J. R. JOHNSON ..... Philosophical Transactions, 1822, pp. 437–446; 1825, pp. 247–253.

C. E. VON BAER ..... Ueber die Planarien. Nova Acta, tom. xiii. pt. 2 (1827), p. 690.

DUGÈS ..... 1. Recherches sur l'organisation et les mœurs des Planariés. Ann. Sci. Nat. xv. (1828), p. 139.

2. Aperçu de quelques observations nouvelles sur les Planaires et plusieurs genres voisins. Art. 3. Planaires. Ann. Sci. Nat. xxi. (1830) pp. 81–90.

EHRENBERG ..... Turbellaria. Symbolæ Physicæ. 1830.

MERTENS..... Untersuchungen über den innern Bau verschiedener in der See lebender Planarien. Mém. Acad. St. Pétersb. 6e sér. tom. ii. (1833) pp. 3–19.

EHRENBERG ..... Die Akalephen des rothen Meeres und der Organismus der Medusen der Ostsee. Abhandl. Berlin Akad. 1835, p. 181.

Dr. GRAY ..... Zoological Miscellany, 1835, p. 5.

F. SCHULZE ..... De Planariarum vivendi ratione et structura Dissert. Berol. 1836.

Dr. CANTOR..... On the Flora and Fauna of Chusan. Ann. & Mag. Nat. Hist. ix. (1842) p. 265.

CHARLES DARWIN ..... Brief descriptions of several terrestrial Planariæ and of some marine species, with an account of their habits. Ann. & Mag. Nat. Hist. xiv. (1844) p. 241.

A. S. OERSTED ..... Entwurf einer systematischen Eintheilung Plattwürmer. 1844.

A. DE QUATREFAGES ..... Études sur les types inférieurs et de l'embranchement des Annelés. Mémoire sur quelques Planaires marines. Ann. Sci. Nat. sér. 3, tom. iv. (1845) p. 129.

LEONARD JENYNS ..... Observations in Natural History. London, 1846.

FREY und LEUCKART ..... Lehrbuch der Anatomie wirbelloser Thiere. Leipzig: C. Voss, 1847.

E. BLANCHARD ..... Recherches sur l'organisation des Vers. Ann. Sci. Nat. vi. (1847) pp. 106–116, viii. (1847) pp. 143–149.

H. FREY und R. LEUCKART.. Beiträge zur Kenntniss wirbelloser Thiere. Braunschweig, 1847.

E. O. SCHMIDT ..... Die Rhabdocœlen des süssen Wassers. 1848.

K. M. Diesing ..... Systema Helminthum, vol. i. 1850. Vindobonæ. W. Braumüller.

J. Leidy ..... 1. Helminthological Contributions, No. 3. Proc. Acad. Philad. 1850–51, vol. v. pp. 241–289.

2. Proc. Acad. Philad. 1858, p. 171.

Sigmund Max Schultze .. 1. Beiträge zur Naturgeschichte der Turbellarien. Erste Abth. Greifswald, 1851.

2. Bericht über einige im Herbst 1853 an der Küste des Mittelmeeres angestellte zootomische Untersuchungen. Verhandl. phys.-med. Ges. Würzburg, iv. (1853) p. 222.

3. Zoologische Skizzen. Zeits. f. wiss. Zoologie, iv. (1853) p. 178.

4. Beiträge zur Kenntniss der Land-Planarien nach Mittheilungen des Dr. Fritz Müller in Brasilien und nach eigenen Untersuchungen. Halle Abhandl. 1856, iv. p. 20.

Sir John G. Dalyell..... The Powers of the Creator displayed, vol. ii. 1853.

Layard ..... Rambles in Ceylon. Ann. & Mag. Nat. Hist. 2nd ser. vol. iv. (1853) p. 225.

Leydig ..... Zoologisches über einige Strudelwürmer. Müller's Archiv, 1854, p. 284.

W. Stimpson ..... 1. Prodromus descriptionis animalium evertebratorum quæ in Expeditione ad Oceanum Pacificum Septentrionalem a Republica Federata missa, Johanne Rodgers duce, observavit et descripsit W. Stimpson. Pt. 1. *Turbellaria Dendrocœla*. Proc. Acad. Philad. 1857, p. 19.

2. On the genus *Bipalium*. Silliman's Journal of Science, May 1861, 2nd ser. xxxi. p. 134.

Ludw. K. Schmarda ..... Neue wirbellose Thiere beobachtet und gesammelt auf einer Reise um die Erde. Bd. 1. Turbellarien, Rotatorien, und Anneliden. Erste Hälfte. Leipz. 1859.

O. Schmidt..... Die dendrocœlen Strudelwürmer aus den Umgebungen von Grätz. Zeits. für wiss. Zool. Siebold und Kölliker. Band ii. Heft 1, p. 24. 1859.

Pease ..... Proc. Zool. Soc. London, 1860, p. 37.

E. Perceval Wright .... Notes on *Dunlopea*. Ann. & Mag. Nat. Hist. 1860, vol. vi. p. 54.

P. J. van Beneden..... Recherches sur la Faune littorale de Belgique. Turbellariés. 1860.

E. O. Schmidt ..... Zeitschrift für wiss. Zool. Siebold und Kölliker, tom. x. (1860) p. 26.

Untersuchungen über Turbellarien von Corfu und Cephalonia. Zeits. für wiss. Zool. Siebold und Kölliker, 1861, Band xi. Heft 1.

Ueber *Planariæ torvæ* Auctorum, *ibid.* p. 89.

Ed. Claparède ..... Études anatomiques sur les Annélides, Turbellariés &c. observés dans les Hébrides. Mém. Soc. Phys. de Genève, 1861, tom. xvi. p. 71.

Ed. Claparède et Alois Humbert. Description de quelques espèces nouvelles de Planaires Terrestres de Ceylon, par M. Alois Humbert, suivie d'observations anatomiques sur le genre *Bipalium*, par M. Edouard Claparède. Mém. Soc. Phys. de Genève, 1861, tom. xvi. p. 293.

C. M. Diesing ..... Revision der Turbellarien, Abtheilung Dendrocœlen. Sitzungsbericht Akad. Wiss. Wien, 1861, p. 488.

H. Rathke..... Beiträge zur Entwicklungsgeschichte der Hirudineen, von Heinrich Rathke, herausg. und theilweise bearbeitet von R. Leuckart. Leipzig: Engelmann, 1862.

Noll ..... Zool. Garten, 1862, p. 254.

Ed. Claparède ..... Beobachtungen über Anatomie und Entwickelungsgeschichte wirbelloser Thiere. Leipzig: W. Engelmann, 1863.

R. Leuckart ..... Die menschlichen Parasiten. Erster Band. Leipzig und Heidelberg, 1863.

W. Carmichael M'Intosh, M.D., F.L.S. On the Structure of the British Nemertians and some new British Annelids. Edinb. Roy. Soc. Trans. xxv. 1869, p. 305.

Franz Leydig ..... Vom Bau des thierischen Körpers. Handbuch der vergleichenden Anatomie, Band i. erste Hälfte.
Tafeln zur vergleichenden Anatomie. Tübingen, 1864.

El. Mecznikow ..... Ueber *Geodesmus bilineatus*, nob. (*Fasciola terrestris*, O. F. Müller), eine europäischer Land-Planarie. Bull. Acad. des Sci. St. Pétersb. tom. ix. (1866) p. 433.

A. Kölliker ..... Icones Histologicæ, oder Atlas der vergleichenden Gewebelehre, herausgegeben von A. Kölliker. Leipzig: Engelmann, 1866.

Ed. Grube ..... Ueber Land-Planarien.
1. Jahres-Bericht der schlesischen Gesell. für vaterländ. Kultur, 1866, p. 61.
2. Reise der österreichischen Fregatte 'Novara' um die Erde. Zoologischer Theil, 2. Band, 3. Abth. p. 45. Anneliden.

Sir John Lubbock ..... Note on the discovery of *Planaria terrestris* in England. Proc. Linn. Soc. x. (1868) p. 193.

W. Keferstein ..... Beiträge zur Anatomie und Entwickelungsgeschichte einiger See-Planarien von St. Malo. Abhandl. d. k. Ges. d. Wiss. zu Göttingen, 1868, B. xiv.

G. Rolleston ..... Forms of Animal Life. 1870.

Rev. W. Houghton ..... On two species of Land-Planarians from Borneo. Ann. & Mag. Nat. Hist. 1870, vol. vi. p. 255. See also pages 347 & 495 *ibidem*.

Gegenbaur ..... Grundzüge der vergleich. Anatomie. Zweite Auflage. Leipzig, 1870.

Dr. F. Sommer und Dr. L. Landois. Beiträge zur Anatomie der Plattwürmer, von Dr. F. Sommer und Dr. L. Landois. Erstes Heft. Ueber den Bau der geschlechtsreifen Glieder von *Bothriocephalus latus* (Bremser). Leipzig: W. Engelmann, 1872.

As regards the foregoing bibliography of the anatomy and zoology of the Dendrocœlous Turbellaria, it may be sufficient to remark that the two memoirs by Dugès deserve perusal and attention even at the present day, though written with reference to freshwater species exclusively (with the single exception of the marine species which I have myself used in this paper for purposes of comparison), and at a period when the microscope was a very different instrument from the one I have employed. As regards the correctness with which the organs in relation with the generative outlet were identified by Dugès and Von Baer respectively, there is no doubt that the French naturalist has the advantage. Dugès's anatomical description (*loc. cit.* xv. p. 163, 1828) of the water-vascular system is, speaking roughly, correct; he would have done well, however, to have adhered to his original view of its intimate connexion with the nervous system; and the demonstration of the large share of truth which this view embodies, as established definitely by Quatrefages (Ann. Sci. Nat. 1845, iv. pp. 172–177), marks an epoch of advance in our interpretation of the anatomy of the entire order. Schultze, writing in 1852 (Zeits. f. wiss. Zool. iv. p. 187), is a little too summary in his condemnation of the method of injection as employed by Blanchard (Ann. Sci. Nat. 1847, sér. 3, tom. viii. p. 146). On the other hand, Schultze would, judging from the analogy furnished by our own Land-Planarians and by all freshwater species, appear to be right (Halle Abhandl. 1856, p. 33) in accusing Blanchard, in his description of *Polycladus*, of having mistaken the tail of the animal for its head. The *Geoplauæ* dissected by Schultze (*loc. cit.* p. 33) appear to have had their reproductive organs in a state of quiescence.

I shall now proceed to describe in detail the anatomy of the Ceylon Land-Planarians, and also that of certain structures of some freshwater and marine species, after a short account of the methods employed in the investigation.

Methods.

The methods employed in the investigation of the anatomy of Planarians were the following:—

In Ceylon the animals were placed, whilst still living, either in a large quantity of strong alcohol, this alcohol being changed after the lapse of twenty-four hours, or they were put into a weak solution of chromic acid, the solution being gradually strengthened as they became rigid, when, after remaining in the chromic-acid solution for about a week, they were transferred to strong alcohol. As soon as the specimens reached England they were placed in absolute alcohol. Portions of the bodies of the animals thus prepared were imbedded in the usual manner in a mixture of sweet oil and white wax. Sections were made in various directions with razors wetted in absolute alcohol*; they were stained with a simple solution made by boiling carmine in water with a few drops of ammonia solution, and leaving the resulting fluid exposed to the air in order to obtain as neutral a solution as possible. The sections, after being stained and washed with water, were treated with absolute alcohol, rendered transparent with oil of cloves and mounted in dammar varnish. All the operations had, in the majority of cases, to be performed on the glass slide, the sections being too fragile to allow of transference. Some sections were also mounted at once in dammar varnish unstained, especially those prepared from specimens hardened in chromic acid. Some of the minuter details of structure were best to be observed in the chromic-acid preparations, and the nervous system especially was only to be seen, with any clearness, in sections made from specimens thus prepared; but it is almost impossible to prepare sections of large area from such specimens, owing to the brittleness of their tissue. Such sections were therefore made from animals hardened in alcohol, and the relations of the various organs to one another thus determined. The sections of *Dendrocœlum lacteum* figured were prepared from specimens which had remained about a year in strong glycerine, and which were transferred thence to absolute alcohol before cutting. Specimens thus prepared afford far better preparations than specimens placed in alcohol directly.

Lastly, dissections with scalpels and scissors of spirit specimens of *Bipalium Diana* were made under alcohol in the ordinary manner.

The sections of the Sea-Planarian, *Leptoplana tremellaris*, employed were made from a specimen which had been preserved in ordinary spirit for a number of years, and not with a special view to histological examination. The sections were stained and treated in the same manner as those of the Land-Planarians.

* Though it is expensive to use absolute alcohol for this purpose it is much better to do so. Absolute alcohol thoroughly wets a razor, forms an even film all over its surface, and allows a large section to be made with much greater ease than is the case if ordinary alcohol be employed.

Keferstein (*loc. cit.* xiv. 1868) employed similar methods to those here described for the investigation of *Leptoplana tremellaris* and other Sea-Planarians; but he does not mention having used carmine, whence probably his somewhat imperfect account of the structure of the cerebral ganglia, and his failure to recognize the water-vascular system in *Leptoplana tremellaris*. There is no doubt that the use of carmine in such cases as this is of great assistance; and several important anatomical details described in the present paper would have been missed had the preparations made not been stained: the water-vascular system, *e. g.*, would probably not have been recognized at all.

Max Schultze recommends a solution of chromate of potash for the preservation of Planarians for microscopic purposes.

The investigation of the anatomy of such animals as Planarians, except in cases in which they are perfectly transparent, is only to be carried out, with any certainty as to results, by such methods as those here described. Schmarda and Blanchard, trusting to ordinary dissection with a scalpel, described series of ganglia in *Bipalium* (*Sphyrocephalus*), Schmarda (*loc. cit.*), and *Polycladus Gayi*, Blanchard (*loc. cit.* p. 147), respectively, which were probably in each case only the ovaries and testes, and certainly not ganglia, and made a number of other blunders. And Claparède's account of the anatomy of *Bipalium*, apparently derived from the employment of similar methods, is very meagre and in part incorrect. The method of sections is, however, rather tedious, and in the course of this investigation more than forty dozen microscopic slides of sections of Planarians had to be prepared and preserved for careful comparison.

Anatomy.

For a general preliminary notion of the broader features of the anatomical arrangement of *Bipalium* and *Rhynchodemus*, reference should be made to Plate XII. figs. 1, 2, & 3, and their accompanying descriptions. The various structural parts will here be considered *seriatim*.

Tegumentary System.—The outermost investment of *Bipalium* and *Rhynchodemus* consists of a well-defined epidermic layer (Plate X. figs. 5, 6, & 7). This layer is seen in the figure first cited to be comparatively thin on the median line of the dorsal surface and that of the ambulacral line, whilst it is thicker in the lateral regions of the body. When the vertical section in a simple stained preparation mounted in dammar varnish is examined with a high power, the epidermic layer appears to be made up of a number of elongated elements lying closely packed together and arranged with their longer axes at right angles to the surface of the body. In these preparations it is impossible to make out any definite form amongst these elements, or any thing like a nucleus in them (Plate XI. figs. 1 & 2, and Plate XV. fig. 9). The cuticle of the common freshwater Planarian, *Dendrocœlum lacteum*, presents in similarly prepared specimens a similar separation into elements by lines passing at right angles to the surface (Plate XIV. fig. 7, E). Occurring in this epidermic tissue are very numerous gland-cells (Plate X.

fig. 10) and rod-like bodies (Plate X. fig. 9), and also in great abundance bodies like A (Plate X. fig. 10), which are irregular elongated masses of finely granular material which stain deeply with carmine; and as they are often seen to be in connexion with the glands beneath the skin, are probably masses of slime hardened by the spirit in the act of their extrusion by those glands. The gland-cells and rod-like bodies are usually far more numerous than they appear in fig. 1, Plate XI.: they present various curious forms in spirit preparations; those seen in Plate X. figs. 9 & 10 are common; but these forms are unnatural and due to shrinking.

If a vertical section of the epidermis be treated with a solution of caustic potash the contracted tissue swells up, and it presents the appearance represented in fig. 4, Plate XI., which is probably very nearly that which exists in the living state. The epidermis here is seen to be made up of large gland-cells (G) and cells containing rod-like bodies (R) and a certain amount of vertical filaments. The gland-cells are large oval sacs with granular contents, and are very like those which may be seen in a living *Planaria torva*. From the appearance presented by gland-cells altered by the action of spirit, as in B, fig. 10, Plate X. (which is the form most usually to be met with), it would appear that these cells burst at the extremity and discharge their contents. The cell appears to have a double wall, for an irregular crumpled membrane is to be seen often within it, evidently shrivelled up by the action of spirit. The rod-like bodies ("Stäbchen-Körperchen"), when acted on by potash, are seen to be of an elongated cylindrical form, with rounded ends and with a closely fitting investing membrane, which appears to be usually attached below by a sort of peduncle to the basement membrane. The irregular filaments which fill up the interspaces between the gland-cells and rod-like bodies appear to be the remains of the cell-walls of gland-cells and rod-like bodies, a violent discharge of rod-like bodies and mucus having probably taken place when the animals were put into spirit or chromic acid. The entire substance of the epidermis is probably made up, in the living condition, of cells resembling the gland-cells described, but of various dimensions, and of cells containing rod-like bodies. I was unable to detect cilia on other parts of the body, except in the region of the papillary line on the head, which will be described with the special sense-organs, and on the living membrane of the mouth and its cavity. Cilia are, however, probably present all over the body-surface, although they must be much weaker and more easily destroyed than those which are situated on each side of the ambulacral line, which were found to be invariably present in all specimens, and which require further study in the fresh state for their perfect elucidation. Max Schultze (*loc. cit.* 4, p. 34) found cuticular cells present in *Geoplana*, though they are absent in the smaller aquatic Planarians. *Geoplana* had, however, remarkably enough, no "Stäbchen-Körperchen," which is remarkable; they perhaps escaped observation, as only one specimen was available for examination.

Cilia.—On each side of the ambulacral line in *Bipalium*, and also in *Rhynchodemus*, the epidermis alters its character. It becomes far thicker and apparently less definite in structure; and it is here clothed with long and stout cilia (Plate X. fig. 5), which

probably assist the muscular movements in the act of progression. Max Schultze (*loc. cit.* 4, p. 34), though he did not see the cilia in *Geoplana*, yet concludes that it must be covered all over with them from the experiments of Fr. Müller (p. 23), who covered the body of one of these Planarians with arrowroot, and observed a motion of the particles which seemed to show the presence of cilia. Darwin came to the same result from the observation of the motion of air-globules in the slime of *Geoplana*. Mecznikow found the skin of *Geodesmus bilineatus* covered with cilia. The alteration in structure of the epidermic layer where it carries the strong ambulacral cilia is remarkable; there are no rod-like bodies or gland-cells at all in this region, which seems to be entirely devoted to the production and working of the cilia.

Basement Membrane.—The epidermic elements in *Bipalium* rest on a very fine basement membrane, homogeneous in structure. The basement membrane is, in transverse sections of the body, with difficulty to be seen as a structure separate from the external circular muscular coat which lies immediately beneath it; but in favourable preparations it is easily distinguished by its much deeper staining with carmine (Plate XI. fig. 1, B). In longitudinal sections the external circular muscular coat is seen in section, and then the basement membrane stands out in considerable relief (Plate XV. fig. 9, B). This basement membrane is not to be confounded with the thick membrane often described as such in Nemertines and Planarians, and which, as will be seen further on, is the homologue of the external circular muscular coat. The basement membrane is perforated for the discharge of the secretion of the subcutaneous glands and the passage of the rod-like bodies, the parent cells of which are situated beneath it. A definite basement membrane could not be detected with certainty in *Rhynchodemus*.

Subcuticular Region.—Immediately beneath the basement membrane is the external muscular system, consisting of a circular and longitudinal series of fibres, which will be considered under the heading "Muscular System." Beneath this system, again, is the zone of loose tissue before referred to, which is occupied by fibres continuous with the radiating muscular fibres of the body, which form a loose stroma, in which are situated the parent cells of the rod-like bodies, a large quantity of glands, the pigment, and also the eye-spots, which latter will be most conveniently considered with the nervous system. The parent cells of the rod-like bodies (Plate XI. fig. 1, R G) are arranged beneath the external longitudinal muscular layer at a tolerably even depth; they are, in spirit specimens, of an elongated oval form, with the upper extremity drawn out to a point or long filament, which in some cases may be seen to reach up to the basement membrane. In spirit specimens they assume various forms (Plate X. figs. 11 & 12); and I was at first led to believe that they actually contained dart-like bodies like those described by Mecznikow in *Geodesmus bilineatus* (*loc. cit.*), which he calls "Nessel-Organe," which he found in vacuoles in the animal's skin, which seemed to be shot out when the animal was pressed under the covering-glass, and which were developed in glands beneath the epithelial layer. But after more careful observation, and especially comparison of the corresponding organs in *Rhynchodemus* with those of *Bipalium*, I came to the con-

clusion that the curiously and often spirally contorted appearance of these parent cells was merely due to the action of spirit on a highly elastic investing membrane, and the bodies shown in fig. 8 were merely débris of such a membrane. In *Rhynchodemus* these cells may often be observed uncontracted and of an oval form, and containing two or three rod-like bodies (Plate XI. fig. 2), in fact in every way resembling the rod-cells described from ordinary aquatic Planarians. On treatment with potash, the cells of *Bipalium* swell up (Plate XI. fig. 4), are seen to contain rod-like bodies, and the fine filament at the upper extremity appears like a duct leading to the surface of the basement membrane. In sections of the integument taken parallel to the surface, the parent cells of the rod-like bodies are seen to occupy positions opposite the interval between the stout external longitudinal muscular fibres (Plate XI. fig. 5); and when cut through transversely (Plate X. fig. 11), they prove to be divided into two or three compartments, and to be provided with a very stout horny-looking cell-wall. In vertical sections they are usually seen to contain more than one rod-like body, often three, in apparently different stages of development. The cells have usually a nucleus-like body at their inferior extremity. The rod-like bodies and their parent glands are distributed all over the body, except on the ambulacral line and the special sense-line on the anterior margin of the head; they are far less numerous on the under surface of the body than on the upper. There can be very little doubt that the organs here described are the homologues of the well-known "Stäbchen-Organe" of aquatic Planarians; and it is almost certain that the organs described by Mecznikow as existing in *Geodesmus bilineatus* come within the same category. He makes a great point of saying that *Geodesmus* has no "Stäbchen-Körperchen," but has "Nessel-Organe." The only difference is that his rod-like bodies are pointed instead of blunt. It may fairly be concluded that these peculiar skin elements in all Planarians, and probably in all Turbellaria, are homologous, though they differ more or less in details of structure. Whether these bodies are also homologous with the nettle-cells of Cœlenterata is another question, and one which will not here be discussed; it has been fairly gone into by Gegenbaur (*loc. cit.* p. 171) and by Max Schultze (*loc. cit.* 1, p. 15).

I much regret that I did not carefully examine the skin-organs of *Bipalium* in the fresh state whilst I was in Ceylon; but I am not certain that I should have derived much benefit, for I am more and more convinced that the study of tissue in the fresh condition should succeed and not precede that of sections of the hardened structures in all histological investigations of soft parts. It is only when a thorough knowledge of the relations and relative sizes &c. of the various elements has been gained in preparations in which they may be observed *in situ*, that we are able to derive much information from the investigation of tissues in the recent state.

Pigment.—The pigment of the body is entirely confined to this, the subcuticular, region, if we except a certain small amount of liver-like pigment to be found in some diverticula of the digestive organs. The pigment, as in the medicinal leech (Leuckart, *loc. cit.* p. 638) and in other Planarians (Max Schultze, *loc. cit.* 1), is of three colours,

yellow, black, and brown, and exists as minute rounded particles embedded more or less thickly in multiramified, transparent, and homogeneous protoplasmic masses: these protoplasmic elements (Plate XI. fig. 1) have usually a larger or main mass, which lies almost immediately beneath the external muscular system, in the same position as that occupied by the parent cells of the rod-like bodies; and from this main mass as a centre they send out fine branched thread-like processes, which ramify amongst the loose radiating muscular elements and the gland-tissue, and sometimes penetrate as far as between the fibres of the internal muscular system, and occasionally pass outwards in an opposite direction a short distance between the epidermic elements. These masses are sometimes densely crowded with pigment-granules, which are very dark and well defined; sometimes they contain hardly any at all; and occasionally the pigment-granules are absent from a circumscribed spot on the principal mass, which gives the spot the appearance of a nucleus. Keferstein (*loc. cit.* p. 15) speaks of the pigment of Planarians as being soluble in alcohol; such is certainly not the case with that of *Bipalium* or *Rhynchodemus*, nor with the eye-pigment, at least, of *Leptoplana*. A *Leptoplana* which had been preserved in spirit for several years had the eye-pigment in perfect condition. The pigment-masses occur more or less irregularly all over the body in *Bipalium Diana* and *B. Ceres*, except on the ambulacral line, which is quite free from them. Where there are well-defined stripes on an animal's body the pigment is arranged accordingly; and thus in the transverse section of *Rhynchodemus* (Plate X. fig. 7) the dark spots are seen to be gathered up into three lines, one median and two lateral, corresponding to the three dark stripes on the animal's back.

Glandular Tissue.—The same zone which contains the pigment-cells and parent cells of the rod-like bodies is also thickly beset with elongated, irregular, and more or less branched masses, which stain themselves an intense colour with carmine, and are filled with coarsely granular contents. It is these bodies which were said to be observed to be continuous with similar irregular projecting masses found amongst the epidermis (Plate X. fig. 10), and which were considered to be slime hardened by the action of alcohol in the act of its ejection by the subcutaneous glandular bodies just described. These glandular bodies ramify often in an arborescent manner, but do not run into such fine threads as the pigment-masses; there is no nucleus to be detected in them. They are not confined to the zone here under consideration; they are also present in greater or less quantity all over the body, even in the septa between the intestinal diverticula, and especially abundant in a region just exterior on each side of the body to the testes. In *Rhynchodemus* they are developed internally to a much greater extent than in *Bipalium*, as will be seen by a comparison of figs. 5 & 7, Plate X.; they are also very conspicuous in preparations, from their being so deeply stained with carmine.

The internal masses of this gland-substance present slight differences from those which are external and subcutaneous. Thus their contents are on the whole less coarsely granulated, and their processes finer. In the main water-vascular canal, which

is occupied by a fine network of connective tissue, the fine connective-tissue threads spring from masses exactly like these latter in appearance (Plate XIV. fig. 6, X).

In Planarians the tissue-elements are morphologically in a rudimentary condition. In the lower Planarians there is a large amount of slimy protoplasmic undifferentiated, or sparingly differentiated, tissue; in the Land-Planarians before us the differentiation is more perfect, but, at the same time, elements which probably perform very different functions are still, in many cases, hardly to be distinguished morphologically. The gland-cells, connective-tissue threads, and pigment-bodies are all of them more or less perfect differentiations of a primitive protoplasmic substance, which may be considered to represent the connective tissue of higher animals. LEUCKART (*loc. cit.* p. 639) in the same manner says of the pigment-bodies of the medicinal leech that they belong to the connective-tissue elements, and resemble the rest of this substance found in the body, and (p. 640) refers to the great resemblance of the gland-cells in this animal to connective tissue. In *Bipalium* and *Rhynchodemus* the differentiation of these several structures has not gone so far as it has in the leech. The subcuticular glands of these Planarians probably represent the superficial glands of the leech called by LEYDIG "einzellige Hautdrüsen" (*loc. cit.* Taf. i. fig. 6); whilst those situate deeper in the substance of the body represent the deeper set of glands of that animal, which, singularly enough, are described by LEUCKART as being more like transparent vesicles, and not so granulated in appearance as the superficial set, which exactly corresponds to what is found to be the case in *Bipalium* and *Rhynchodemus*. The resemblance in many points of structure between the leech and these Planarians is most striking; and if sections of the skin treated in the same manner be examined side by side, the similarity in appearance is most remarkable, the pigment and glandular bodies being most alike, and the absence of "Stäbchen-Organe" being the most striking difference. The glandular and connective-tissue masses appear to be represented in the lower Planarians by the structures described and figured (*loc. cit.* 1, fig. 24) by MAX SCHULTZE as "sehr zarte Fädchen mit Ausschwellungen;" but here there was yet no distinction between glandular and connective tissue. The "Binde-Substance" observed by KEFERSTEIN in *Leptoplana* is of the same nature; and so are probably also the "plasmatische Kanäle" described and figured by SOMMER and LANDOIS (*loc. cit.* p. 10), which in the figure have the same granulated appearance as the glands of *Rhynchodemus* and *Bipalium*, and of which they state that their finest twigs form connexions with processes of connective-tissue-like bodies. As reference will not again be made specially to the connective tissue of the Planarians under consideration, it should be stated that an irregular network of slimy connective tissue is to be found all over the body between the muscles and around the various organs; it is often seen to be connected with the large irregular masses which so closely resemble the glandular substance.

Those portions of it which are specially developed to form capsules for the generative organs and the network in the water-vascular canals will be described with those organs. The basement membrane of the skin has already received description. The subcutaneous

glandular masses are well developed all over the body, except on the ambulacral line: at the sides of this organ, where the long cilia are, they are quite absent, but a very few are occasionally to be seen along its median line. In the head of *Bipalium* there is an unusual development of the internal glandular system, as will be seen by reference to Plate XIV. fig. 3. In longitudinal sections of the body taken in a direction parallel to its ambulacral surface, there may be observed in the region of the mouth an irregular tree-like arrangement of the internal glandular masses, but no definite duct or termination of this glandular tree was to be discovered.

Remarkable Glandular Masses in Bipalium Ceres.—In *Bipalium Ceres* a remarkable structure was met with which could not be found in either of the other species of *Bipalium* examined.

In this species, on the ventral surface, is a pair of peculiar ridges which run longitudinally along the entire length of the body. The ridges are situate at the line of junction of the convex superior surface of the animal's body with its flatter ventral surface. When viewed with a lens, these ridges merely appear as elevations or pinchings up of the integument. They were present in all specimens of *Bipalium Ceres* examined. In vertical sections of the body of this species, such as that figured in Plate X. fig. 6, these ridges are seen to contain peculiar oval masses (A, A). These masses presented a fine granular structure, very like that which has been described as characterizing the glandular tissue of *Bipalium Diana* and *Rhynchodemus*. No further structure could be made out in them; but from these oval masses an irregular tract of similar glandular matter, disposed in elongated masses as in the skin-glands, could be traced up to a point a little above the testes. The oval masses and their accompanying glandular tracts were not to be seen in every successive vertical section, but occurred at slight intervals. But a satisfactory longitudinal section of the ridges could not be obtained in order to show the amount of separation between the gland-masses in it, or whether there was any regularity in their arrangement, the tissue of the specimens of *B. Ceres* being somewhat soft. No special opening corresponding to the gland-masses could be detected along the line exteriorly. These organs in *B. Ceres* are of great interest, and need further investigation, which I hope that the expected arrival of a large number of specimens from Ceylon will permit of. It is possible that these gland-masses, with their accompanying tract of glandular matter, may be a foreshadowing of the segment-organs in Annelids, which, in the leech at least, as is well known, make their appearance in development as solid masses of tissue, and subsequently become hollow (Leuckart, *loc. cit.* p. 704).

Muscular System.—Great stress has been laid by various authors on the supposed fact that whilst in Annelids, Nematoids, Trematodes, and, in fact, all higher worms, the external coat of the body was arranged circularly, and the internal longitudinally, in Turbellarians the reverse was the case; and the statement has been made in such a form that it really appeared as if an inversion of the muscular coats must be supposed in order to get at the proper homological relations of the muscular structures. And

hence there appeared to be a wide gulf fixed between the Planarians and their really very near allies the Leeches. A study, however, of the muscular arrangement of *Bipalium* and *Rhynchodemus* shows that in these animals the muscular arrangement is almost identical with that in the leech; and, further, that that which exists in the lower Planarians and also in the Nemertines is easily reducible to the same type.

In *Bipalium* and *Rhynchodemus* the muscular arrangements are of very great complexity, and may be regarded as belonging to two systems, superficial and deep. The general arrangement of each system will first be considered, and then the special arrangement found to exist in the ambulacral line, this being a purely muscular organ, and therefore properly described in this place. The special muscular arrangements which hold in the generative and digestive organs will be described under the headings of these systems.

Superficial Muscular System.—Immediately beneath the thin basement membrane of the epidermis of *Bipalium* and *Rhynchodemus* is a layer of closely apposed muscular fibres. This layer is clearly to be distinguished all over the body; but it varies in thickness in different regions, and also in the arrangement of its fibres, although the general trend of these latter is always circular. This layer may be seen in Plate XI. fig. 1 (E. C. M.) or, with its fibres seen in section, in Plate XV. fig. 9 (E. C. M.). It is thickest on the dorsal region, and inferiorly on each side of the ambulacral line. In these regions also the arrangement of its fibres is most complex: this arrangement is displayed diagrammatically in Plate X. fig. 13; a sort of basketwork of fibres running in three directions is formed; and an almost exactly similar arrangement of fibres is described as existing in the external muscular coat of higher worms, in the leech and Nematodes, by Leuckart (*loc. cit.* pp. 459, 645). When this muscular coat is viewed from above, the fibres are seen crossing one another diagonally, whilst others take a directly transverse or circular course (Plate XI. fig. 5).

The decussating fibres are thus doubly oblique in their direction. At the sides of the body this muscular coat is almost entirely absent, and especially in *Rhynchodemus* (Plate XI. fig. 2). The muscular coat appears to be almost homogeneous and structureless; in fact it exactly resembles the external coat of aquatic Planarians, such as *Leptoplana tremellaris* (Plate XIV. fig. 1, E. C. M.) or *Dendrocœlum lacteum* (Plate XIV. fig. 7, E. C. M.), though in this latter instance the external coat is more evidently muscular. Now the remarkable arrangement of fibres which is common to both groups being taken into consideration, there can be little doubt that the external circular muscular coat here described in *Bipalium* and *Rhynchodemus* is the homologue of the similar external coat of the leech; and it is evident that the external coat of *Dendrocœlum lacteum* answers to that of *Bipalium*, and that of *Leptoplana tremellaris* to that of *Dendrocœlum lacteum*. The body investments are essentially homologous; but muscular elements are developed in them more perfectly in some forms than in others, and in some parts of some forms more perfectly than in other parts. In higher worms the development of fibres is almost constantly perfect in all parts of the body. Keferstein

and other observers have called the external tissue of the Planarians they have examined a basement membrane, and have therefore described longitudinal muscles as being external in that animal—which no doubt is correct from one point of view, since it is probably impossible to detect any muscular fibres in the external tissue of the body; but still it is apt to lead to an erroneous conclusion. The great fact to be borne in mind is that, whatever this external tunic may be called, it is the homologue of the external circular muscular coat of higher worms and *Bipalium*, and that therefore the distinction between the arrangements of the muscular system in the two groups is of very little importance. M'Intosh (*loc. cit.* p. 310) lays great stress on the fact that in *Ommatoplea alba* the circular muscles are external and the longitudinal internal, whilst in *Borlasia* the reverse is the case; and accordingly he regards these two worms as belonging to very different types indeed. Now it would be difficult to overestimate the wide gulf which would exist between these two forms if there were really any inversion of the muscular coats here; but the external circular coat of *Ommatoplea* is evidently the homologue of the thick external tunic of *Borlasia*, called by M'Intosh the basement membrane, since in *Ommatoplea* there is said to be no basement membrane, and the external circular muscular coat lies immediately beneath the epidermis, as does the so-called basement membrane of *Borlasia*. It will be noted that the extremely thin and delicate basement membrane which intervenes between the external circular muscular coat in *Bipalium* and the epidermis has nothing to do with the thick tunics (as I believe, improperly termed basement membranes) of *Borlasia* and *Leptoplana*. These latter are probably contractile, and perform the part of muscular tunics, although no definite fibrillar arrangement has been detected in them. Immediately beneath the external circular muscular layers are the longitudinal muscles of the superficial muscular system. These muscles do not form a continuous tunic to the body as the circular muscles, but occur as isolated bundles of fibres. The fibres composing these bundles are remarkably stout, and the bundles themselves are arranged beneath the external circular layer at tolerably regular distances from one another, the intervals between them being the situation occupied by eye-spots and the fine upper extremities of the parent cells of the rod-like bodies (see below, p. 144 *seqq.*), and also by terminations of the radiating muscular fibres. These longitudinal fibres are well seen in section in Plate XI. figs. 1, 2, & 9 and Plate X. fig. 13, and as viewed from the surface of the body in Plate XI. fig. 5. In *Rhynchodemus* the fibres do not form such definite isolated bundles as in *Bipalium*, as may be seen by a comparison of figs. 1 & 2 in Plate XI. The muscular system generally in *Bipalium* is far more highly specialized than it is in *Rhynchodemus*. This longitudinal system of muscles is most fully developed in the middle of the dorsal surface of the body and in the infero-lateral regions, in correspondence with the greater elaboration of the external muscular coat in those regions already described.

This superficial longitudinal muscular system is evidently represented in the leech by the few longitudinal fibres which, according to Leuckart (*loc. cit.* p. 645), are to be

found sparingly present between the layers of the external circular muscular coat of that animal. The superficial muscles, both circular and longitudinal, are to be found all over the body-surface of *Bipalium* and *Rhynchodemus*, except on the under surface of the head of *Bipalium*, where they appear to be absent, being nevertheless well developed on its superior aspect. In the ambulacral line their arrangement is greatly modified; but the description of this modification will be given when the general muscular structure of the ambulacral line is considered. Max Schultze, in describing *Geoplana* (*loc. cit.* p. 35), says that the longitudinal muscles are external as in other Turbellarians; but as he only had one specimen to work at, and apparently did not examine that by means of sections, it is possible that a delicate external circular coat was overlooked.

Deep Muscular System.—A broad zone, already described, occupied by loose radiating muscular fibres and various skin-organs, intervenes between the superficial and deep muscular systems in *Bipalium* and *Rhynchodemus*. Internally to this zone the whole of the body may be regarded as made up of a dense mass of muscular fibres, in which are hollowed out the digestive tract, water-vascular canals, and space for the generative system, and the interstices of which are more or less filled up with glandular matter and connective tissue. The muscular mass consists of fibres which in their general arrangement may be described as longitudinal, circular, and radiating.

In a transverse section of *Bipalium* or *Rhynchodemus*, longitudinal fibres are seen in cross section, dotted all over the central mass of the body, but in certain regions they are much larger and more numerous than in others. Thus they form a conspicuous zone on the periphery of the central gastro-intestinal tube near the commencement of the intestinal diverticula, as may be seen in Plate X. fig. 5; and in this zone the fibres are especially stout and closely aggregated infero-laterally, where they appear in section as irregular masses separated from one another by fibres of the radiating system. A similar aggregation of fibres forms a pair of longitudinal bands which run the entire length of the body, one on each side of the ambulacral line. A further special development of longitudinal fibres is constituted by a group of small fibres around the oviduct. Over the remainder of the central body-mass the longitudinal fibres are scattered pretty evenly; they are entirely absent in the zone of loose radiating fibres intervening between the central muscular mass and the skin-muscles, and in the main water-vascular trunks.

Circular and radiating Muscular Fibres.—There is no separate and distinct circular muscular layer in the inner muscular mass, though fibres more or less circular in their direction are dispersed all over the body-mass; an especial number of these is to be found at the lateral regions of the body, just externally to the extremities of the intestinal diverticula. In *Rhynchodemus* the circular fibres in the corresponding region are more highly developed, and form a tolerably well-defined layer, lying just externally to the internal mass of longitudinal fibres, as may be seen from Plate X. fig. 7 and Plate XI. fig. 2; and this layer appears to be homologous with that which exists in *Lepto-*

plana tremellaris, Plate XIV. fig. 1, E. C. M. In *Bipalium* and *Rhynchodemus*, as will be seen from Plate X. fig. 5, the arrangement of the muscular fibres is extremely complex; and although a general distinction may be drawn between fibres which take a circular course and those which take a radial one, and are prolonged outwards to form the zone of radial fibres, yet the two sets of fibres run into one another, and no sharp line of distinction can be drawn between them. In Planarians with a less highly specialized muscular system, such as *Dendrocœlum* or *Leptoplana*, the case is different, and here the muscles are sharply divided into systems. The radial fibres of *Bipalium* and *Rhynchodemus* appear to correspond with the vertical or dorso-ventral fibres of these aquatic species, whilst the irregularly disposed circular fibres are homologous with the definite circular layer of the same animals.

Radial fibres pass outwards in *Bipalium* and *Rhynchodemus* in every direction, to form the clear zone already described as existing beneath the skin-muscles. Specially stout muscular fibres, derived from the circular system, pass transversely immediately beneath the digestive tract (Plate X. figs. 5 & 6), and a series of transverse fibres in the region of the ambulacral line is to be found about the level of the inferior boundaries of the main water-vascular canals (Plate X. fig. 5). Stout vertical fibres form the lateral walls of the central digestive tube, and mingled with these are finer fibres which bend over to form a sort of circular muscular layer to the intestinal tube. The septa between the diverticula of the intestine are formed by very fine fibres, which are continuous with fibres belonging to the body-mass, and which may be seen in Plate X. fig. 5 (where portions of the septa remain *in situ*) to have a decussating arrangement. A similar arrangement may be seen in *Rhynchodemus* (fig. 7). Max Schultze (*loc. cit.* 4) remarks on a difference between the special muscular fibres of the intestine in *Geoplana* and the other motor body-muscles; and the extreme fineness of the muscular fibres of the intestinal septa above mentioned points to a similar histological differentiation in *Bipalium* and *Rhynchodemus*.

When viewed in longitudinal sections, the circular muscular fibres of the body-mass are seen to take the same oblique direction with regard to the long axis of the body which is to be observed in the external circular muscles. The fibres decussate in a similar manner, and take then a more or less spiral course. In the head, bundles of fibres may be seen crossing one another along the middle line, and spreading out right and left towards the margins of that curious semilunar structure.

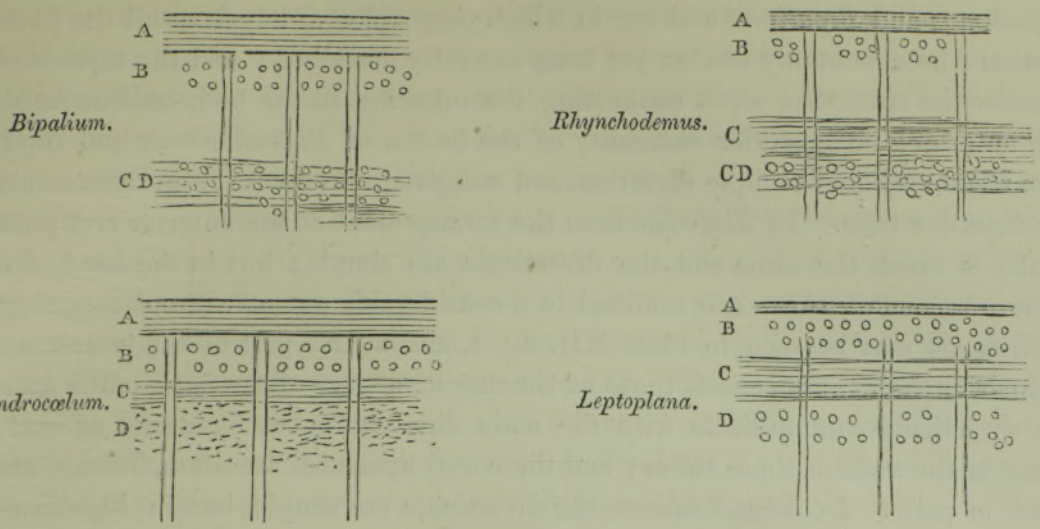
Ambulacral line.—In *Bipalium*, just before the contour of the under surface of the body begins to swell out to form the projecting ambulacral line, the external circular muscular layer splits into two parts (Plate XI. fig. 3)—one external, which, preserving the same direction which it takes in the other regions of the body, forms a thin layer immediately beneath the basement membrane of the skin; the other passes directly inwards, towards the median muscular mass of the ambulacral line, and its fibres then separating spread out fanwise and become lost in this mass. In so doing it separates off a series of smaller longitudinal muscular bands from the larger one, forming the

regular external layer of longitudinal muscles. This latter layer, after being continued a short distance inwards, is lost. The series of smaller longitudinal muscular bands is continued all over the ambulacral line, as may be seen by reference to the figure referred to above. The stout vertical muscles of the line swell out as they pass between these longitudinal bundles to end at the external transverse or circular muscular layer. In *Rhynchodemus* the ambulacral line is merely marked by an absence of pigment, and a slight increase in strength of the vertical fibres.

In *Dendrocœlum lacteum*, as may be seen from Plate XIV. fig. 7, a well-defined external circular muscular coat exists, to which are attached the stout bundles of vertical or dorso-ventral fibres. The dorso-ventral fibres pass between bundles of longitudinal fibres, just as do the radiating fibres of *Bipalium* and *Rhynchodemus* between the superficial longitudinal muscular bundles. The cells of the rod-like bodies lie just beneath and between the bundles of longitudinal fibres, in fact bear the same relation to them as in *Bipalium* and *Rhynchodemus*. Internally to these well-defined muscular elements, and between these and the digestive cavity, is an interval filled up with a pulpy tissue, which is not so perfectly differentiated histologically. In this tissue are embedded the thread-cells and connective-tissue elements, and in cavities excavated in its substance the generative organs and water-vascular system. It evidently corresponds to the internal muscular mass of *Bipalium*. On its outer margin can be traced fibres having a circular arrangement; but I was unable to detect a second series of definite longitudinal fibres in it.

In *Leptoplana tremellaris* (Plate XIV. fig. 1) the external circular muscular coat is reduced to a mere membrane, and this is succeeded by a layer of longitudinal fibres. In their histological development the elements of the body-mass lying internally to this are much more perfectly differentiated than in *Dendrocœlum lacteum*. The internal circular muscular layer is well defined, and is succeeded in most regions of the body by a region occupied by numerous longitudinal fibres. It appears, then, on the whole, that the arrangement of the muscular fibres in the bodies of Planarians, and indeed all Turbellarians, is essentially the same as that in other worms. The external muscular coat is circular, the internal longitudinal, though in some cases the external coat becomes rudimentary, and appears as a simple membrane; and this may occur in different parts of the same animal. The external longitudinal muscles are succeeded by internal circular muscles, distinctly marked as a separate layer in *Leptoplana*, and just to be made out as such in *Dendrocœlum*, interspersed between the internal longitudinal fibres of the body-mass in *Bipalium* and *Rhynchodemus*, but in this latter forming in some parts of the body a distinct layer, as in *Leptoplana* (see Plate X. fig. 7). The interval forming the zone occupied by radiating fibres in *Bipalium* and *Rhynchodemus* is absent in the flattened aquatic species.

The following diagrams represent the arrangements and homologies of the various muscular layers in *Bipalium*, *Rhynchodemus*, *Leptoplana*, and *Dendrocœlum* (A, external circular layer; B, longitudinal; C, D, internal circular and longitudinal muscular systems respectively):—



Digestive System.—As is usually the case in Planarians, the digestive canal is single anteriorly and double posteriorly in both *Bipalium* and *Rhynchodemus*; and a similar condition exists in *Geoplana* (Max Schultze, *loc. cit.* 4, p. 35). From the opening of the pharynx into the digestive tract forwards there is a single straight and broad digestive tube, which gives off diverticula or cæca on each side, and breaks up into ramifications in the head. At the opening of the pharynx this single tube becomes split into two branches, which diverge widely to pass one on each side of the sheath which contains the pharynx and which forms their inner wall; they approach one another somewhat more closely as they pass on each side of the sheath containing the generative organs, which lies immediately behind that of the pharynx and is continuous with it. Posteriorly to this point a stout septum runs down the median line of the body to the very tip of the tail, and separates the two tubes from one another, forming their inner wall on each side. This septum is continuous with the sheath of the generative organs superiorly; and, indeed, these organs and the pharynx might justly be said to be contained in spaces hollowed out in the septum itself. These points are displayed in Plate XII. fig. 2.

There is no perforation in the septum, and thus the two posterior canals have no communication with one another behind the point at which they branch off from the single anterior tube. From the outer surface of the lateral walls of the digestive canals arise stout transverse septa, which pass outwards to join the lateral region of the muscular body-mass. These septa are parallel both in *Rhynchodemus* and *Bipalium*, excepting at the immediate anterior and posterior extremities of the animal. The intervals between them are diverticula or cæca, which communicate with the intestinal tube by means of apertures in its wall. These diverticula are present in the posterior part of the body only, on the outer side of the two intestinal tubes, as is also the case in *Geoplana* (Darwin, *loc. cit.* p. 243). The parallelism, approximation, and enormous number of digestive diverticula form the characteristic point of resemblance between

Rhynchodemus and *Bipalium*, and one in which they differ widely from all the flattened Planarians whose anatomy has as yet been carefully described; and the septa seem to foreshadow the transverse septa connecting the intestine to the body-wall in Annelids. In the anterior and posterior extremity of the bodies of *Rhynchodemus* and *Bipalium* the diverticula take an oblique direction, and are given off fanwise from the termination of the digestive tube. In *Rhynchodemus* the arrangement at the anterior and posterior extremity is much the same and the diverticula are simple; but in the head of *Bipalium* these secondary tubes are ramified to a considerable extent without retaining any parallelism, as may be seen in Plate XII. fig. 1, and at this part of the body resemble very much in their ramifications those of the digestive tract of the flat aquatic species.

The diverticula communicate with the main digestive tubes by means of oval perforations in the walls of those tubes; and these oval apertures are often, but not always, disposed in pairs. In *Rhynchodemus* the diverticula are simple, but in *Bipalium* they are partially split up into two or four compartments by means of secondary and tertiary septa, which extend from their outer extremities through a portion of their length. The septa, when cut transversely in a longitudinal section of the animal's body, are found, both in *Rhynchodemus* and *Bipalium*, to consist of two muscular walls, between which is a quantity of the peculiar glandular matter already described as existing in the other parts of the body. The muscular fibres of the septa are, as has been also stated, finer than those of the general body-mass; but occasional stout fibres, taking a more or less vertical direction, are to be seen in transverse sections of the septa. In the neighbourhood of the pharynx, the wall of the main anterior digestive canal is strengthened by special longitudinal muscular fibres. The pharynx, or muscular prehensile apparatus forming the entrance to the digestive tract, and by means of which the food is taken into the body, is contained in a receptacle or sheath formed of the same material as the median septum of the posterior portion of the digestive tract and continuous with it. This sheath has an extremely elongated oval form in *Bipalium*, and a shorter oval one in *Rhynchodemus*; and it communicates with the exterior in each case by means of a circular aperture, which has been termed the mouth. In *Geoplana* the mouth is described by Mr. Darwin as being a transverse slit, not circular, as is here the case. The pharynx, which, when the animal is in search of food, is protruded through the mouth, lies ordinarily entirely out of sight within its sheath, to the dorsal surface or wall of which it is attached by strong muscular roots. Claparède was mistaken in supposing that a folded pharynx was characteristic of Land-Planarians. Though the pharynx of *Bipalium* is thus constructed, that of *Geodesmus bilineatus* (Mecznikow, *loc. cit.*) and of *Rhynchodemus* is cask-shaped or cylindrical. The pharynx of *Bipalium* has been described and figured by Claparède. It is (Plate XII. fig. 3) of an elongated form, and consists of a pair of closely apposed tumid lips, thrown by contraction into a series of transverse folds. Between the lips, somewhat anteriorly to the centre of the organ, is the aperture which leads, by means of a short canal, to the opening (O, Plate XII. fig. 3) into the digestive tract, which opening lies just in front of the anterior

termination of the sheath of the pharynx. The muscular attachment of the pharynx to the roof of its sheath is confined to the region immediately surrounding the tube by which it leads into the digestive tract, and it is thus anterior to the middle of the organ, and forms a sort of pedicle. The oral aperture lies immediately over the centre of the pharynx. In *Rhynchodemus* the pharynx has the form of a cylinder directed antero-posteriorly, and narrowed in front and behind, and which may thus be said to be cask-shaped ("*doliiformis*," Stimps.). The pharynx is perforated in the direction of its length by a tube which runs directly into the digestive tract, entering it by an aperture having the same relation to the sheath of the pharynx as in *Bipalium*. The pharynx is attached to its sheath only at its anterior extremity. The cylindrical form of pharynx is evidently the older and simpler one, and is that invariably possessed by the lower Rhabdocœle Planarians. The folded mouth of *Bipalium* is to be regarded as a modification of that of *Rhynchodemus*, the mouth of the cylinder having been gradually spread out until the whole organ became a flattened sucker, which, when retracted and packed away, assumes the form shown in the figure. Regarding this as being the case, and considering therefore the long irregular slit between the lips of the pharynx of *Bipalium* to be homologous with the rounded aperture at the extremity of the cylindrical pharynx of *Rhynchodemus*, the muscular arrangement in the two cases will be found to be identical. The pharynx is built up of an internal and an external set of longitudinal and circular muscular fibres, which muscular masses are connected by transverse fibres, in the interstices of which is a quantity of glandular matter. The outer muscular wall consists of external fibres, which run from the point of attachment of the pharynx towards the margin of its aperture or lips, and which must therefore be considered longitudinal. These longitudinal fibres, as will be seen from Plate XII. fig. 9, are extremely stout, and are succeeded inwardly by a zone of circular fibres, internally again to which are transverse or radiating fibres crossed by scattered circular fibres, and with stout longitudinal ones in their interstices. A wide zone, occupied by loosely packed radiating fibres, only intervenes between the outer muscular tissue of the pharynx and its inner longitudinal and circular muscles (Plate XII. fig. 8); and in this wide zone is a considerable quantity of glandular tissue, which is more abundant in *Bipalium* than *Rhynchodemus*. The inner circular muscular coat which clothes the tubular cavity of the pharynx immediately beneath its epithelium is composed of densely packed fibres, and stains, as do the corresponding inner circular tissues in the penis, vagina, &c., very deeply with carmine. The exterior of the pharynx and the walls of its sheath are lined with an epithelium, in which no definite cell-structure could be observed; but it appeared transparent and marked by vertical lines, which might represent separation into cellular elements. In the interior of the pharynx the epithelium is, especially towards the margin of the lips or aperture, composed of long pear-shaped elements, which were ascertained from chromic-acid preparations to be in *Bipalium* covered with cilia, and which are probably ciliated in *Rhynchodemus* also, although no ciliation was discernible in spirit preparations.

The interior of the digestive tract is clothed with a thick glandular investment, which varies slightly in its structure in the various regions of the body. In the region of the mouth, the lining of the main digestive tract consists of peculiar rounded bodies arranged irregularly in rows at right angles to the surface, and gathered into elongated groups, so as to have a certain resemblance to the gastric glands of vertebrates (Plate XV. fig. 15). These rounded bodies are imbedded in a finely granular matrix. The glandular lining of the diverticula is made up of rounded or pear-shaped elements, with finely granular contents and occasional nuclear bodies; and in places these cells are distended into large transparent sacs with nuclei, and they then closely resemble those which form the glandular cells of the digestive tract of *Planaria torva*, which are figured in Plate XV. fig. 14. The lining of the cæca is much thinner than that of the main antero-posterior digestive tubes. The lining of these latter always partakes more or less of the form displayed in Plate XV. fig. 15, although that structure is best marked in the neighbourhood of the mouth. The glandular lining in the diverticula is often, especially in the head, tinged with a brown pigment; and it is highly probable that these diverticula discharge a function somewhat like that of the hepatic tubes of Annelids, whilst the glandular lining of the main tract has a gastric function. I found no traces of vegetable matter in the digestive tracts of any of the many specimens of *Bipalium* and *Rhynchodemus* examined by me, nor, indeed, any distinctly recognizable foreign body at all. The digestive tube close to the mouth, in one specimen of *B. Ceres*, contained a mass of apparently animal matter; but it was so far decomposed or digested that I could not determine its exact nature. The diverticula of both *Bipalium* and *Rhynchodemus* contain numerous gregariniform parasites, which are also to be found imbedded in the neighbouring tissue: hardly any diverticulum is free from them, and they are usually massed together at the blind ends of the diverticula.

Water-vascular System.—In vertical sections of the body of *Bipalium* and *Rhynchodemus*, such as those figured on Plate X., there are to be seen a pair of rounded spaces lying one on each side of a region immediately above the ambulacral line, and thrown out into relief by the fact that they are always very little tinged with the carmine-staining fluid. In *Bipalium* these spaces are separate, but in *Rhynchodemus* they are connected by a broad transverse tract; and when sections of this animal are viewed under the microscope, the resulting figure, resembling somewhat a pair of spectacles in shape, is the most striking feature of the preparation. The spaces are irregularly oval in form, with the long axis of their figure directed transversely; and throughout the entire length of the body they present nearly the same figure on section, except in the region of the pharynx and generative organs, where they are necessarily somewhat contracted. The spaces bear a constant relation in position to the oviduct and testis in the anterior portion of the body. The oviducts lie, in *Bipalium Diana*, *B. Proserpina*, and *Rhynchodemus Thwaitesii*, just above the space on each side, somewhat exteriorly to its middle line; whilst in *Bipalium Ceres* they lie just within the space itself, but in the same region as in *B. Diana*. The testes in all these species lie just externally to the spaces on each

side, at the same level with them, and closely abutting on them. In *Dendrocœlum lacteum* similar spaces, situate at equal distances from the median line of the body and towards its ventral surface, are to be seen in a transverse section of the animal's body (Plate X. fig. 8, W, W). These spaces are, as in the Land-Planarians, little stained with carmine; and the oviduct (OD) also has exactly the same relation to them. There can be no doubt as to the homology of these spaces with one another; and, as will be seen further on, they are remarkably similar in their minute structure. The spaces (W, W) in *D. lacteum* are the main water-vascular trunks seen in section, and those of the Land-Planarians, as homologous with them, must receive the same appellation. The water-vascular trunks of *Leptoplana tremellaris* are found similarly situated and constructed on section (Plate XIV. fig. 1, W). Part of one of the drawings of Sommer and Landois's paper on the sexually mature joints of *Bothriocephalus latus* has been reproduced in Plate XIV. fig. 2, in order to show the very close resemblance in structure between the lateral vessels of that worm and those of the Planarians. In *Bipalium* and *Rhynchodemus* the pair of main vascular trunks extend throughout the entire length of the body, preserving their relative position to the ambulacral line and body-structures generally. In *Rhynchodemus* they terminate abruptly with rounded ends at both extremities of the body, as may be seen, as far as the anterior extremity is concerned, in Plate XIV. fig. 5. In *Bipalium*, on the other hand, the vascular trunks, though terminating posteriorly as in *Rhynchodemus*, spread out in the anterior extremity in an irregularly ramified manner (Plate XIV. fig. 4), the ramifications being imperfectly defined by rows of vertical muscular fibres. The wide expansion of the vascular trunks in the head of *Bipalium* is seen in vertical section in Plate XIV. fig. 2. Frequent branches are given off from the vascular trunks in both *Rhynchodemus* and *Bipalium*; and in some preparations they are conspicuous by their not being stained with carmine. These branches usually take a transverse course, and are in reality irregular lacunæ, having no more definite wall than their main trunks. The large transverse trunks connecting the main trunks in *Rhynchodemus* have already been spoken of: these are seen in longitudinal sections to be a series of irregular transverse channels hollowed out in the intervening muscular mass, and separated from one another by irregular intervals. Other finer transverse channels may be traced passing off from the vascular trunks (Plate XIII. fig. 15), being especially well seen in *Rhynchodemus*. As will be seen from Plate XIV. fig. 4, the large vascular space in the head of *Bipalium* does not extend to the verge of that structure, but is separated from this by a zone of solid tissue. Through this zone of tissue proceeds in straight lines a series of fine branches or tubular spaces, which are directed outwards to the margin of the head, and appear to pass directly to the peculiar ciliated sacs which there exist, and possibly to communicate through these with the exterior. These branches are figured, as seen in a longitudinal and horizontal section, Plate XV. fig. 3; and one may be sometimes traced passing from the lateral extremity of the vascular space to the papillary line in the vertical section, Plate XIV. fig. 3. The relation of these branches to the ciliated sacs will

be more carefully considered when these latter organs are treated under the head of special sense-organs. The structure of the spongy tissue with which the water-vascular spaces are filled is very remarkable. In *Bothriocephalus latus*, as in *Leptoplana*, *Dendrocœlum*, *Bipalium*, and *Rhynchodemus*, it is characterized by being very little stained with carmine (SOMMER and LANDOIS, *loc. cit.* p. 13). The tissue forms a fine reticulation, in which are pierced oval or rounded openings. A comparison of figs. 1, 2, & 7, Plate XIV., will show the remarkable resemblance of structure in the various worms. In *Bipalium* and *Rhynchodemus* the main water-vascular trunks are traversed by muscular fibres of the body-mass, which give a characteristic appearance to these structures, from the circumstance that they form two parallel sets, which preserve a constant direction throughout the body and cross one another at a constant angle. One set is nearly vertical in *Bipalium Ceres* (Plate X. fig. 6), slightly inclined inwards (*i. e.* towards the middle line) inferiorly in *B. Diana* (Plate X. fig. 5), and inclined rather outwards in *Rhynchodemus Thwaitesii*. The other set has about the same inclination in all these species, and will be seen to slope downwards and outwards on each side at an angle of about 60° with the vertical. The two sets of fibres thus crossing include between each other rhomboidal spaces. The fibres are here said to be muscular, because they are continuous with undoubted muscular fibres of the body-mass; but, as will be seen in Plate XIV. fig. 6 (where a portion of one of the main vascular trunks of *Bipalium Diana* is shown greatly magnified), these fibres give off ramifications which are histologically continuous with the fine connective-tissue network occupying their interspaces, and this, again, in direct connexion with the peculiar protoplasmic elements (X, X) which have been before treated of.

I observed no cilia within the vascular canals of any of the Planarians which I examined.

The term "water-vascular system" has here been given to the peculiar canals or spaces in *Bipalium* and *Rhynchodemus*, because they are most evidently of the same nature as the lateral vessels of *Tænia* and *Bothriocephalus*, to which that name was given by V. SIEBOLD, and because they are distinctly homologous with the longitudinal canals of *Dendrocœlum* and *Leptoplana*, which usually receive that appellation. But the term would seem to be rather unfortunate, because a "water-vascular system" has come to be regarded more or less as necessarily an excretory organ ("Excretions-Organ," KEFERSTEIN, *loc. cit.*), and to have necessarily some communication with the exterior. The term "primitive vascular system" would seem to be more appropriate; for the case would seem to be as follows. In primitive animal forms of more or less homogeneous constitution, as advancement in organization proceeds, a circulation of the body-fluids becomes a necessity, and vascular spaces become gradually developed in certain parts and along certain lines of the body-mass. These spaces become more and more clearly defined, and assume at length the form described as existing in *Bipalium*, where the spaces or canals are by no means as yet open channels, but merely tracts where the body-tissue has become extremely porous and permeable to fluids, and which are still traversed

by stout muscular fibres. These canals, however, subserve in this animal all the purposes of imperfect circulation required, and even, by means of their branches, may effect the erection of the penis, and perhaps also the distention of the pharynx (KEFERSTEIN, *loc. cit.* p. 21), as do the blood-vessels of higher forms.

This primitive vascular system, which in *Tænia* and *Bothriocephalus* assumes a very definite and tubular form, though still occupied internally by spongy tissue, is directly homologous with the body or perivisceral cavity, which is persistent throughout life in *Branchiobdella*, and present in all leeches at some period of development, and in all adult leeches, in a rudimentary condition at least (LEUCKART, Die menschl. Paras. p. 666). The true blood-vessels are, when present, developed within and partitioned off from this primitive vascular system. In *Tænia* and Planarians no such further development has taken place. The nervous system lies within the primitive vascular system; but when blood-vessels are developed, the nervous system is often included within the latter. In some animals there are further developed, from without inwards, ciliated tubes, sacs, or pores, which communicate with the primitive vascular system, by means of which excretion from the vascular system takes place; and such an arrangement reaches its highest development in such forms as the Trematodes. It is, however, erroneous to consider the main and necessary function of the primitive vascular system as excretory, since in such forms as *Bipalium* it obviously performs many other circulatory functions, although here, as in Trematodes, it may also subserve an excretory function by means of the ciliated sacs in the region of the head. MERTENS (*loc. cit.* p. 12, 1833) describes the ganglia of *Leptoplana* as hearts, and the nerves given off from them as vessels. DUGÈS held a like opinion (*loc. cit.* 1, 1828). It seems highly probable that this is to be explained by the fact that the nerve-ganglia of this Planarian, and probably of all others where such exist, lie within a vascular sinus, a part of the primitive vascular system, and in continuation with it, the sinus giving off branches in which the nerve-branches lie. I cannot agree with KEFERSTEIN in supposing that BLANCHARD'S injection of the sinus round the ganglia of *Leptoplana* and its branches resulted from unskilful manipulation, and does not represent the true state of the case (KEFERSTEIN, *loc. cit.* p. 21). I had only one spirit-specimen of *Leptoplana* available for examination; but in this the ganglia were seen on section to be surrounded by a space occupied by loose spongy tissue, very little stained by carmine and exactly resembling that seen in the vessels of *Bipalium*, and the nerves occupied broad tracts of similar appearance; and on a vertical transverse section being made of the body, the two canals filled with spongy tissue were cut across, exactly resembling those of *Bothriocephalus* in structure, and coinciding in position with the large pair of longitudinal body-nerves. QUATREFAGES (Sur les Planaires, p. 172) says the brain is placed in a cavity or lacuna, prolongations of which accompany the viscera. He figures no regular water-vascular system apart from this. It is especially to be remarked that, almost invariably, observers who figure the nervous system of Planarians distinctly, do not in the same animal give the vascular system, and *vice versâ*. Thus OSCAR SCHMIDT (Zeitschrift für wiss. Zool. x. 1859, p. 29) speaks of seeing in a

Planarian the water-vascular system very imperfectly, but two long and stout "Seiten-Nerven" very plainly. Every line of evidence seems to point to the fact that in all Planarians, and indeed all worms in which a special blood-system is not differentiated off from the primitive vascular system or body-cavity, the nervous system lies within the vascular canals and spaces; and in *Bipalium*, as will be seen in the sequel, what was believed to be the nervous system was found to occupy such a position.

It is an interesting fact, and I believe new to science, that there exist Planarians which contain in their body-fluids hæmoglobin. I detected this substance by means of the spectroscope in a small Planarian, apparently a species of *Derostomum* (Schmarda, Neue wirb. Thiere, Band i. Hälfte i. Taf. i. fig. 8), which I found infesting in considerable abundance the surface of the integument of an echinoderm, one of the *Clypeastridæ*, Ag., which abounds at Suez. It is possible that the red colour of many other Planarians is due to the presence of hæmoglobin. A red tinge may be seen at the base of the eye of *Dendrocœlum lacteum*, but I found it too faint to give any absorption-spectrum. The reddish colour of the ganglia of Nemertines would be well worth testing.

Generative System.—The generative organs of Land-Planarians have hitherto been very imperfectly described, these animals having apparently never before been studied by means of sections, which is the only way of arriving at a satisfactory result in the case of opaque and solid worms such as these. Blanchard, speaking of *Polycladus Gayi* (*loc. cit.* p. 149), says that the generative organs are not well preserved in spirit; but there can be no doubt that what he calls a nervous system were the testes and ovaries. Schmarda made the same mistake in the case of *Bipalium*. Max Schultze could only find a penis and seminal receptacle in *Geoplana*. Claparède figures the general appearance of the mass containing the intromittent organs in *Bipalium*; but he calls the uterus the penis, and failed altogether in his description of the organs, probably from want of adequate material. He found no testes or ovaries. Schmarda, by some unaccountable mistake, describes his *Sphyrocephalus* (=*Bipalium*) as having two generative orifices.

The general arrangement of the generative organs will best be understood by reference to Plates XII. & XIII. and their description. We shall consider in order the ovaries and their duct, the testes with their duct, and the receptive, anal, and intromittent organs.

Ovaries.—The single pair of ovaries (Plate XII. figs. 1 & 3, OV.) is placed, in both *Bipalium* and *Rhynchodemus*, in the anterior extremity of the body or head at an enormous distance from the uterus, with which they communicate by means of a long and slender duct. The ovaries themselves are simple sacs, pear-shaped in *Bipalium*, spherical in *Rhynchodemus*, and they lie imbedded in the stout longitudinal muscles of the body-mass, which separate from one another and form cavities for their reception. The ovaries have a distinct but delicate membranous capsule, on the inner surface of which are to be seen marked out a series of irregular spaces (Plate XIII. fig. 8), which may represent a cellular lining. Externally to the capsule is a wide space occupied by an irregular meshwork of connective tissue, with large interspaces, which is probably in connexion with the primitive vascular system and supplies nutritive fluids to the organ; a similar

arrangement exists in the case of the testes. The ovary was filled, in all the specimens which I examined, with ova in all stages of development, the riper ova occupying the central and lower regions of its cavity, and the less mature the peripheral.

A meshwork of connective-tissue fibres with spindle-cells upon them passes from the walls of the ovary between the ova, and apparently furnishes the capsules in which the mature ova are seen to be contained. This meshwork is best seen in *Rhynchodemus* (Plate XIII. fig. 13). The successive stages in the development of the ova are given in Plate XIII. fig. 12. In its earliest stage the ovum is indistinguishable from the cellular lining of the sac of the ovary: it then apparently becomes rounded and increases in size, the germinal vesicle as well as the surrounding yelk remaining finely granulated up to a certain stage; then the germinal vesicle clears up and becomes transparent, and the ovum becomes enclosed in a capsule with a transparent area between it and the capsular wall. The final stage consists in the development of transparent fatty looking vesicles or globules within the fine granulated yelk-area. I am uncertain whether the capsules here described as enclosing the ova in their latest stages descend with them into the uterus, or whether they are merely ovarian follicles which open in the ovary and allow of the escape of the ripe ova. From a study of the ovary of *Rhynchodemus*, in which these capsules are not so well marked, and when present more apparently connected with the stroma of the ovary, I was led to consider that such was probably the case. If it be so, then it is quite possible that several ova may subsequently be enclosed within one true egg-capsule formed in the uterus, as in *Dendrocœlum lacteum*. At the base of the cavity occupied by the ovary of *Bipalium* is a mass of small rounded spindle-cells, which may represent an accessory gland in a rudimentary condition. In one specimen of *Bipalium* which I examined there was present on each side, just externally to the lower extremities of the ovaries, a small mass of large nucleated cells (Plate XIII. fig. 8, *g*) connected by a pedicle with the ovary itself. This mass, though extremely well defined in this one specimen, was absent entirely in many others, and present only as a trace in some few. It may represent a yelk-gland in a rudimentary condition, or possibly, as all specimens which I obtained had their testes and ovaries filled with ova and spermatozoa, this accessory gland had already performed its function for the season in the formation of ova, and had shrunk in consequence. The former hypothesis is, however, most probably correct, since the female organs generally in *Bipalium* seem to be undergoing a process of simplification. No corresponding glandular mass was seen in *Rhynchodemus*. The oviduct leaves the ovary on its outer side in *Bipalium*, on its inner in *Rhynchodemus*. The duct consists in both animals of an external well-marked basement membrane, on which rest internally a series of well-defined nucleated cells, which are rectangular in longitudinal section, truncated cuneiform in transverse section. These cells bear long hairs or cilia, which are inclined in a direction from the ovary towards the uterus, and in transverse sections of the oviduct show a spiral twist (Plate XIII. fig. 9). The hairs are in many parts of the oviduct so long that it seems possible that they have no vibrating motion, but more probably act merely so as to prevent the

ova, which are driven forwards by muscular pressure, from making a retrograde motion. The exact connexion of the oviduct with the cavity of the ovary in *Bipalium* could not be determined; it was only traced as far as is figured (Plate XIII. fig. 8), where the oviduct is seen to expand as it passes about halfway up the outer side of the ovary. In *Rhynchodemus* the oviduct was found to take origin from a papilla on the upper and inner side of the oviduct, and projecting into its cavity (Plate XIII. fig. 13). The papilla is formed of spindle-cells, and a number of similar cells are to be found scattered in the loose tissue around its base. The oviduct passes up through the loose external capsule of the ovary, and lies externally to the membranous internal capsule. The oviducts are directed in straight lines down the body, and passing just externally to the sheath of the pharynx reach the region of the uterus, to which organ they are directed by a sharp turn inwards (Plate XII. figs. 1 & 6). In *Rhynchodemus* the ducts are directed at first a little obliquely outwards to reach their position immediately internal to that of the vasa deferentia. In both *Bipalium* and *Rhynchodemus* the oviducts are crossed in the lower part of their course by the vasa deferentia, which pass to the dorsal aspect of the ducts. In *Bipalium* this crossing takes place about the region of the oral aperture; in *Rhynchodemus* lower down, opposite the base of the penis. In *Bipalium*, in the region occupied by the posterior portion of the pharynx, and from thence to the uterus, the oviducts have connected with their external aspect on each side peculiar branches or diverticula. These diverticula are very short, and are all directed at a slight angle backwards, *i. e.* towards the animal's tail. There are about six of them on each side, and they are situated at tolerably regular intervals. One of these diverticula is seen highly magnified in Plate XIII. fig. 9. A short branch is seen to enter the oviduct at an angle. The branch is constructed in the same manner as the oviduct itself, and has its cilia directed inwards towards the cavity of the duct. It ends abruptly, as far as definite oviducal structure is concerned, but from its abrupt termination is prolonged an interlacement of connective-tissue fibres, forming a sort of tube or cavity. There can be no doubt that these branches here described are the rudiments of the branched ovary possessed by lower Planarians, such as *Dendrocœlum lacteum*. In *Bipalium* a single one of the branches, the most anterior or terminal one, has become enlarged and differentiated, and has taken on the whole of the ovarian duties: the remaining branches are present in a rudimentary condition, like the yelk-glands: in *Rhynchodemus* both diverticula and yelk-gland have disappeared. Our Land-Planarians are, in fact, in their ovary just like *Polycelis cornuta*, O. Schmidt (Dendrocœlen Strudelwürmer, Taf. iii. fig. 1). The position of the oviduct, as seen in transverse vertical sections, is of great importance: it is always in close relation with the main trunk of the primitive vascular system, lying immediately above it or just within it in *B. Ceres*, and slightly externally to its median vertical line. This position holds good throughout the course of the oviduct in *Bipalium*, *Rhynchodemus*, and, singularly enough, in *Dendrocœlum lacteum* also (Plate XIV. fig. 7), showing how closely related are all the forms; and I was surprised to find in *Dendrocœlum lacteum* the oviduct so far histologically differ-

entiated that it exhibited a well-formed cellular lining, just like that in *Bipalium*. The testes in *Bipalium* (Plate XII. fig. 1) are arranged in pairs along a line just external to that occupied by the oviduct. They commence a short distance behind the ovaries, and extend for about half the interval between the ovaries and the oral aperture. There are about twenty-four or twenty-five pairs; they are separated from one another by short intervals, and communicate by means of lateral apertures with the vas deferens, which passes straight down the body along their inner side to reach the region of the penis. In transverse vertical sections of the body the testes are seen to occupy a position imme diately external to the main primitive vascular trunks in both *Bipalium* and *Rhynchodemus*, and the vas deferens to lie immediately between the vascular trunks and the testis (Plate X. fig. 5, V. D.). The separate testes are in *Bipalium* irregularly spherical; they consist (Plate XIII. fig. 4) of a sac or wall and contents. The sac is formed, as in the ovary, of a fine but dense inner membrane, and an outer loose investment full of irregularly oval spaces, and probably in communication with the vascular system. The whole testis lies imbedded in a cavity amongst the longitudinal muscular fibres, as does the ovary. On the inner side of the spherical testicular sac is an opening, by means of which it communicates with the cavity of the vas deferens; and it would appear that the basement membrane of the vas deferens becomes continuous with the inner membrane of the sac. There is a bulging out of the wall of the vas deferens opposite the spot where the testicular cavity communicates with it, and a sort of sinus is thus formed in it at this place. The vas deferens (Plate XIII. fig. 7) consists of a basement membrane lined with nearly rectangular nucleated cells; these cells are much smaller than those of the oviduct; and the vas deferens is oval in section, not circular, and has a wide lumen. Opposite the opening into the testis the epithelial lining of the vas deferens is thickened in a remarkable manner. The epithelium is not ciliated, as is that of the oviduct. The cavity of the testis is always divided into two regions—an outer broad zone full of immature cells, and a central cavity in which are ripe parent cells of spermatozoa with spermatozoa attached to them in process of development and also in the free condition. The outer zone is so well defined from the inner space that it would almost appear as if a thin membrane were reflected back from the point of union of the vas deferens with the testicular sac-wall, and separated the two regions. I could not, however, make sure of the existence of such a membrane. It appears that the cells, as they become more and more developed within the outer zone, pass gradually outwards away from the opening into the duct till they reach a point opposite this opening, by which time they have reached a high state of maturity; hence they pass into the inner space of the testis, and here give birth to the spermatozoa. It appeared, from the study of a large number of sections, that the large parent cells of the spermatozoa were formed by the aggregation of a number of smaller rounded cells; but such a point could not, of course, be determined with certainty from preserved specimens. The spermatozoa are formed at the periphery of the large parent cells as in Annelids, and at first are provided with pear-shaped heads, which, however, are absent in mature spermatozoa, since some of them were present in the spermatozoa crowding the vas deferens.

In *Rhynchodemus* the testes are not of a definite spherical form as in *Bipalium*, but oval, with one end of the oval drawn out. They are very numerous, packed tightly together (Plate XIII. fig. 15), and they extend along each side of the body as far down as the base of the penis, instead of stopping short halfway as in *Bipalium*. I was unable to find the vas deferens in the anterior part of the testes of *Rhynchodemus*; and it is possible that the successive testicular sacs may here communicate directly with one another, or that thus the whole testis may here be one long moniliform or contorted tube. I had not sufficient material to determine this point. The arrangement of the parent and immature cells is the same as in *Bipalium*. The spermatozoa are linear, and resemble those of *Bipalium*. The losing of the bead-like swelling by mature spermatozoa has been noted by MAX SCHULTZE in other Planarians (MAX SCHULTZE, *loc. cit.* 4, p. 31). The position of the vas deferens in *Bipalium* and *Rhynchodemus* is remarkable as being to the inner sides of the testes, since in the leech it is to the outer sides of those organs.

The male and female intromittent organs form a small mass placed just posteriorly to the pharynx in an excavation into the median septum between the two posterior digestive tubes (Plate XII. fig. 2, G). This mass is seen enlarged in Plate XI. fig. 8. It consists in *Bipalium* of a posterior portion of an inverted flask-shape, with an ovoid body attached to it at a slight inclination anteriorly. The narrow neck of the flask-shaped body stands vertically, immediately over the external generative aperture. At its base anteriorly the body is entered by the oviduct, whilst the ovoid anterior mass is pierced by the vas deferens, which first passes backwards beyond its point of entrance, and then returns upon itself a short distance with a tortuous course to its destination. Plate XI. fig. 6 shows the arrangement of parts within the bodies just described. The external generative orifice opens into a short vestibular cavity, into which superiorly opens the mouth of the flask-shaped mass; leading from the mouth of this mass is a straight vertical vaginal tube, which at its summit bends sharply towards the anterior extremity of the body, and forms a small space, into which open the oviducts, hence termed uterus. In the anterior aspect of the vaginal tube close to its orifice opens the cavity of the ovoid portion of the generative mass, which consists of the sheath containing the penis and its contents: the cavity of the penis-sheath is of the same form as that of the sheath. To its internal surface, at its upper and anterior extremity, is attached the penis, which in its shrunken preserved state does not reach as far as the opening into the vagina.

The external generative orifice is provided with a circular sphincter muscle, and is clothed internally, as is the whole of the vestibule, vagina, and uterus, with ciliated epithelium. The vestibule is provided with a muscular wall, consisting of circular and longitudinal fibres, with radiating fibres interspersed between them, and serving to hold the tubular cavity in place by attaching it to surrounding tissue. The vagina (Plate XII. fig. 6 & Plate XI. fig. 9) has a very dense internal circular coat, external to which is a thick mass of longitudinal and radiating muscular fibres.

The vagina is lined with a densely ciliated epithelium, which rests on a stroma of connective tissue; the lumen of the tube in transverse section is, when the lining of the tube is in a contracted condition as here depicted, cruciform. A quantity of glandular matter of a branched thread-like form passes to the muscular mass containing the vagina from all sides. The irregular threads composing the gland break up into finer branches, which appear to become lost between the longitudinal muscular fibres of the vagina. I at first took these thread-like masses for nerves, but they are evidently homologous with the shell-making glands described by KEFERSTEIN (*loc. cit.* p. 28) in *Leptoplana tremellaris*, and figured originally in the same species by MERTENS. The threads of the gland appeared to become continuous in places with the general glandular matter of the body, which is especially abundantly present in the neighbourhood of the generative organs. It may be that this shell-gland, so highly developed in *Leptoplana*, is here rudimentary and nearly functionless, or possibly it may be in a more active condition at a different period of the year from that at which I gathered my specimens of *Bipalium*. The uterus is provided, like the vagina, with strong circular longitudinal and radiating fibres; it terminates (Plate XII. fig. 4) in a heart-shaped cavity, clothed with a very thick epithelial layer and densely ciliated. At the apex of the heart, *i. e.* inferiorly, there is a papilla, on each side of which opens one of the oviducts, which may be seen in the figure curving inwards to meet at that point, but remaining distinct from one another to the very last. It is probable that the aspect of both vagina and uterus becomes much altered when the egg-capsule is formed, if such be formed. The cavity is probably greatly enlarged, its muscular walls proportionally thinned, and very probably the uterine and vaginal tubes are run into one.

The penis in *Bipalium* is more or less conical in shape. In the base of the cone is a large glandular cavity with a muscular wall, the prostate, into the anterior extremity of which open the vasa deferentia, and from which a tube is continued down the centre of the penis to its tip. The penis has an elaborate muscular structure, for which reference should be made to Plate XII. fig. 5 & Plate XIII. fig. 3. The cavity of its central tube is lined with a glandular epithelium, which rests on spongy tissue: this is succeeded outwards by a dense circular muscular layer; then follows a space occupied by radiating fibres, more or less intertwined, and having canal-like spaces in their interstices and also bundles of strong longitudinal fibres. Externally is a row of delicate longitudinal fibres and a thin layer of circular ones. Finally, the penis is covered with an epithelium, consisting of rounded vesicular elements. The cavity containing the penis is lined with a simple even layer of epithelium, divided by vertical lines into irregular elements, which are apparently without nuclei. The penis is attached to its sheath by means of its radiating and longitudinal fibres, which spread out and invest the large glandular cavity at its base or prostate, and thus form an ovoid muscular bulb. The cavity in this bulb or prostate is lined with a glandular epithelium disposed in a series of follicles (Plate XIII. fig. 2). The epithelium is of the same nature as that found lower down in the central tube of the penis, but is here especially developed: it is very conspicuous

in carmine preparations, from the fact that it remains almost unstained. The glandular elements are transparent and devoid of nuclei; at the mouths of the follicles they are long and tumid, and form finger-like processes, whilst in the cavities of the follicle they are smaller and angular in outline from mutual appressure.

In longitudinal sections of the bulb of the penis there are to be seen running inwards from its periphery to its glandular cavity peculiar wavy bands, which in carmine preparations stand out into relief unstained amongst the surrounding deeply stained muscular tissue (Plate XIII. fig. 2, *u*). Similar structures are to be seen running down the penis longitudinally (Plate XIII. fig. 1, *u*), at pretty regular intervals from one another. When these wavy bands are seen in section, they appear as spaces filled with a fine areolar network, like that exhibited by the primitive vascular system (Plate XIV. fig. 6). I once held that these bands represented a series of tubular canals in connexion with the primitive vascular space, and serving for distending and erecting the penis, in the same manner as, according to KEFERSTEIN's conjecture, the proboscis of *Leptoplana* is distended by injection of body-fluid (KEFERSTEIN, *loc. cit.* p. 21). In highly magnified transverse sections of the penis these wavy bands are seen (Plate XIII. fig. 3) passing inwards between the masses of longitudinal muscular fibres, making their way through the dense zone of internal circular fibres, and breaking up at the inner verge of this zone into a series of fine branches. These branches, as seen in the drawing, which is accurately made with the camera lucida, pass through the loose tissue which intervenes between the epithelium of the glandular prostatic follicles and the internal circular muscular layer, and appear as if they became, in some instances, continuous with the glandular epithelial elements themselves. It seemed possible that this should be the case, and that when the penis was distended with fluid, a liquid derived from that fluid should be poured out by these glands which should serve to dilute the semen. The structure, as shown in the drawing, is very remarkable; but after the examination of an oceanic* Planarian I have come to see that the structure in question is a system of muscles retracting the penis. Running along the centre of the wavy bands may usually be seen fine thread-like structures, and such are indicated in Plate XIII. fig. 3. It is very probable that these are nerves following, as in *Leptoplana*, the vascular canals.

In *Rhynchodemus* the generative organs are somewhat different from those of *Bipalium*, as may be seen from Plate XII. fig. 3 & Plate XI. fig. 7. The penis is larger and longer, both actually and still more so in proportion to the size of the body. There is no large swelling or bulb at the base of the penis, but a strongly muscular straight canal, of larger bore than that which pierces the penis, extends from the base of that organ towards the mouth in the middle line, and terminates blindly just opposite the termination of the testes. This canal is not provided with any special glandular epithelium, and is probably solely ejaculatory in function. The vasa deferentia are wide and tortuous; they turn twice upon themselves before they enter the ejaculatory tube, which they join at a

* This animal came into my hands whilst I was upon H.M.S. 'Challenger,' subsequently to the reading of this paper before the Royal Society.

short distance posteriorly from the anterior fluid extremity. In the female portion of the generative organs there is no definite vaginal tube as in *Bipalium*. The uterus forms a much larger cavity, and the oviducts here unite into a single tube instead of remaining distinct like those of *Bipalium*, and they enter the posterior wall of the organ instead of the anterior.

Looking at the testes and ovaries as shown in *Bipalium* (Plate XII. fig. 1), there can be little doubt that these are the "ganglia" which SCHMARDA described, the ovaries being the first pair. Moreover, BLANCHARD'S similar ganglia in *Polycladus* are almost certainly due to the same cause: the especially large ganglia in what he calls the tail of his animal, but which in reality, as explained by MAX SCHULTZE, was the head, is evidently the ovary, and the remainder of the ganglionic chain the testes. *Polycladus* must therefore be closely related to *Bipalium* in the arrangement of its generative organs.

Nervous System.—There is no trace of the series of ganglia described as existing in *Bipalium* by SCHMARDA, other than the ovaries and testes. After most careful examination I could not discover any thing like a ganglion-cell in the whole body of either *Bipalium* or *Rhynchodemus*. I believe that the nervous system, which is in these Planarians very indistinctly differentiated histologically, forms a meshwork within the primitive vascular canals. In the head such a meshwork is to be observed, in sections made from specimens hardened in chromic acid, occupying the same region and having the same form as the vascular ramifications in the head. A portion of this meshwork is figured, Plate XV. fig. 5. The dark matter at the points of union of the bundles of fibres is merely finely granular in structure and has no cell-structure. Similar tissue may be traced along the whole length of the body in the primitive vascular canals, both in *Bipalium* and *Rhynchodemus*. After very careful examination I have been able to discover no more specialized nervous system in these Planarians than this. The fine threads within the vascular canals in the penis of *Bipalium* are probably nerves; and in *Rhynchodemus* an undoubted and distinct nervous filament is given off from the inner extremity of the eye (Plate XV. fig. 8), but it cannot be traced to connexion with any definite nervous structure; it passes to the main vascular trunk and is there lost. In order to make certain that ganglia such as those known to exist in other Planarians were really absent in *Bipalium* and *Rhynchodemus*, and had not merely been destroyed by the method of treatment, I prepared sections from a specimen of *Leptoplana tremellaris* hardened in spirit in the same manner as my Land-Planarians, so as to display the structure of the nervous ganglia. Figs. 1, 2, 3, & 4, Plate XV., represent four longitudinal and horizontal sections from this specimen drawn with the camera lucida, and are given here to show the remarkable complexity of the structure of the ganglia in this Planarian, and the very great distinctness of the ganglion-cells. Most certainly no such structure as this exists in *Bipalium* or *Rhynchodemus*.

It is constantly asserted by older and even by modern writers that ganglion-cells do not exist in Planarians and Nemertines (FREY and LEUCKART, *loc. cit.* p. 92; LEYDIG, Vom Bau des thierischen Körpers, p. 124). QUATREFAGES (Sur les Planaires, p. 172)

says, "Les deux lobes de cette espèce de cerveau sont composés d'une substance entièrement diaphane et homogène." KEFERSTEIN is the only investigator, so far as I am aware, who has made sections of these organs in Planarians and recognized their true structure, whilst M'INTOSH (*loc. cit.* pl. vii. fig. 2) has figured nerve-cells from the ganglia of Nemertines. KEFERSTEIN gives a figure of a section of the ganglia of *Leptoplana tremellaris*, but the wonderful complexity of the nervous structures is not so minutely treated as in the present drawings.

Special Sense-organs.—The only special sense-organs observed in *Bipalium* were the eyes and the peculiar organs on the anterior margin of the head. In *Rhynchodemus* a single pair of eyes was all that could be found.

The eye-spots which appear when *Bipalium* is viewed with a hand-lens as black specks, are thickly set all over the upper surface of the flat semilunar head, except along its median line, a small space (broader anteriorly) on each side of this, and along a narrow band bordering the actual anterior margin of the head. The eyes are especially densely packed at the tips of the corona of the head, and are thickly set along all its margin, except in the region of the band of special sense-papillæ. Besides this, eyes are present sparingly scattered over the entire length of the body to the very tail. It has hitherto been supposed by all writers on the subject that the eyes were confined to the anterior extremity in *Bipalium*; but the spots are constantly being met with in sections in the region of the mouth and generative organs. CLAPARÈDE, examining the eye-spots of *B. Phœbe*, could not make certain whether they were sense-organs at all. His specimens probably were not in sufficiently good preservation. In *B. Diana*, *B. Ceres*, and *B. Proserpina* the eye-spots are usually of the form shown in Plate XV. figs. 6 & 7, though they are often less elongated and indeed nearly spherical. They consist of a simple sac or cell, the anterior portion of which, or that turned to the light, is transparent and lens-like, whilst the posterior and larger portion of the sac is darkened and rendered opaque by the presence of brown pigment-granules imbedded thickly in its wall. An unpigmented dot, often present in the posterior part of the eye-spots and represented in Plate XV. fig. 6, seems to show that these eye-spots are to be regarded as modifications of single nucleated cells.

In the interior of the eye-spot, when seen in section, is to be observed, under favourable circumstances in deeply stained sections, a lens-like body (Plate X. fig. 7); but this body is very little differentiated from the general cell-contents, and is hard to see. Between the lens-like body and the interior of the pigmented back of the eye-spot is a highly refracting substance. No nervous structures were observed in connexion with the eye-spots. The eyes are arranged beneath the external circular muscular coat of the body, and in the intervals between the external longitudinal muscular bands (Plate XV. fig. 9). The light which reaches them must penetrate the external circular muscles first; but these are not thick in the regions where the eyes are most numerous.

Rhynchodemus possesses only a single pair of eyes, but these are very much larger than those of *Bipalium*; they are elongate, and somewhat like those of the leech in

form; they have a transparent cornea in front, which projects amongst the epithelium of the skin, and a posterior pigmented sac. From the pointed extremity of the sac a nerve-fibre can be traced a short distance. I had not sufficient material to allow of the examination of the internal structure of the eye. LEIDY has given some account of the eyes of *Planaria sylvatica* (=*Rhynchodemus sylvaticus*, Diesing). He says the eyes consist of a vitreous humour, two thirds covered with pigment, and $\frac{1}{500}$ of an inch in diameter. MECZNIKOW (*loc. cit.*) describes the eyes of *Geodesmus bilineatus* as very complex. Their pigment-skin is composed of clearly definite hexagonal cells, and the eye contained a red-coloured crystalline body consisting of rod-like elements. The crystalline body evidently is homologous with the lens-like body in the eye of *Bipalium*, the similarly complex body in *Leptoplana*, and the vitreous body in *Dendrocœlum lacteum*, which has usually a reddish tinge. The eye of *Rhynchodemus Thwaitesii* probably contains a corresponding structure. MECZNIKOW considers that the great complexity of eye of *Geodesmus* has been brought about by the animal's terrestrial habits, it requiring to use its sight more on land than in water; but the eye of *Leptoplana* is as complex as that of *Geodesmus*, and it is possible that the aquatic ancestor of *Geodesmus* was already provided with highly developed ciliated sacs.

In describing the habits of *Bipalium*, I described the manner in which that animal throws out tentacular-like projections from the anterior margin of its semilunar head when in motion, and evidently uses these temporary tentacles as sense-organs. In reading M. HUMBERT'S interesting account of *Bipalium*, I found that he had observed this habit of the animal as well as I, and had been led by his observation to seek for sense-organs or tentacular structures on the margin of the head. He was not successful in finding any; but on very careful examination of well-hardened specimens I was more fortunate, and discovered a narrow band extending along the whole anterior margin of the head, entirely free from pigment, and occupied by a row of cylindrical rounded papillæ placed vertically side by side, and with small oval openings between their superior extremities (Plate XIII. fig. 16). This row of papillæ is in the upper part of the lower fifth of the margin of the head, so that it lies close to the ground when the animal's head is lowered. The papillæ are covered with short cilia; but I could find no special structure in them, except that in their region, and that of the ciliated pits, there is a large quantity of tissue formed of small spindle-cells. The oval apertures between the papillæ lead to ciliated pits, the appearance presented by which is shown in figs. 11, 12, & 13, Plate XV. In longitudinal and horizontal sections the appearance presented in fig. 13 is seen. The light bands, which appear to pass to the bottoms of the ciliated pits, are continuous with the vascular network of the head. Whether they represent tubes in communication here with the exterior I cannot say. They may convey nerves to the sacs. From the manner in which the animal uses the front of its head, there can be little doubt that the papillary line discharges some special sense-function; but it is possible that this function is discharged by the papillæ, whilst the ciliated pits with their communicating vascular stems act as excretory organs. The papillary line with its pits was found in

all the species of *Bipalium* examined. The ciliated sacs in Nemertines come at once, of course, into one's mind in connexion with these curious structures. Careful examination may perhaps give evidence of the existence of similar ciliated sacs in *Geoplana* and other Planarians. Nothing of the kind was found in *Rhynchodemus*.

Summary.

The writer commences by expressing his great obligations to Professor Rolleston, whose pupil he formerly was. Professor Rolleston first informed him of the existence of Land-Planarians in Ceylon, and of the importance of investigating them. The paper was at first intended to be a joint one; and Professor Rolleston himself made a number of preparations of *Rhynchodemus*, one of which is figured. He likewise rendered great aid in the bibliography, and by constant suggestions and assistance during the progress of the work.

Two new species of Land-Planarians from Ceylon are described:—one belonging to the genus *Bipalium* (Stimpson), *B. Ceres*; the other to that of *Rhynchodemus*, *R. Thwaitesii*, so called after Mr. G. H. K. Thwaites, F.R.S., the illustrious curator of the Peradeniya Gardens, by whose assistance the specimens made use of were procured.

Lists are given of all the known species of *Bipalium* and *Rhynchodemus*.

With regard to the habits of *Bipalium*, the most interesting facts noted are that these animals use a thread of their body-slime for suspension in air, as aquatic Planarians were observed to do for their suspension in water by Sir J. Dalyell, and the cellar-slug does for its suspension in air. The projection of small portions of the anterior margin of the head in the form of tentacles, originally observed by M. Humbert, becomes interesting in connexion with the discovery of a row of papillæ and ciliated pits in that region. The anatomy of the Planarians was studied by means of vertical and longitudinal sections from hardened specimens. The skin in *Bipalium* and *Rhynchodemus* closely conforms to the Planarian type, but is more perfectly differentiated histologically than in aquatic species, and approaches that of the leech in the distribution, colour, and structure of its pigment, and especially in the arrangement of the glandular system. The superficial and deep glandular system of the leech are both here represented. In *B. Ceres* peculiar glandular structures exist, which may foreshadow the segmental organs of Annelids, it being remembered that these segmental organs are solid in an early stage of development. Rod-like bodies (Stäbchen-Körperchen) are present in abundance, though, singularly enough, Max Schultze failed to find any in *Geoplana*. These Stäbchen-Körperchen are probably homologous with the nail-like bodies of Nemertines; and it is possible that the setæ of Annelids are modifications of them. No light is thrown by the structure of these bodies in *Bipalium* on the question whether they are homologous with the urticating organs of Cœlenterata.

The muscular arrangement in *Bipalium*, which is very complex, throws great light on the homologies between the muscular layers of *Turbellaria* and other Vermes. It is commonly said that whilst in all other Vermes the external muscular layer is circular,

and the longitudinal internal, in Turbellarians the reverse is the case. A wide gulf is thus apparently placed between these groups. In *Bipalium* there is an external circular muscular coat, which even presents the same imbricate structure which is found in it in leeches and other worms. In *Dendrocœlum lacteum* there is also an external circular coat. In cases where a distinct external circular muscular coat is absent, it is represented by a thick membrane, which is very probably contractile. The question resolves itself simply into a more or less perfect fibrillar differentiation of that membrane. All Turbellarians are built on the same essential type, as regards muscular arrangement, as are other worms. The general muscular arrangements in the bodies of *Bipalium* and *Rhynchodemus* have become much modified from those of flat Planarians by the pinching together and condensation of the body; but they are nevertheless referable to the same type.

The digestive tract consists of three tubes (one anterior, two posterior), as in other Planarians, and as in the embryo leech before the formation of the anus. Characteristic of Land-Planarians, and consequent on the condensation of the body, is the absence of all diverticula from the inner aspects of the two posterior digestive tubes. This is found to be the case in *Geoplana*, *Bipalium*, *Rhynchodemus*, and *Geodesmus*. The close approximation of the intestinal diverticula in *Bipalium* and *Rhynchodemus*, and the reduction of the intervening tissue to a mere membranous septum, is very striking, and seems to foreshadow the condition of things in Annelids. The great difference in the form of the mouth in *Rhynchodemus* and *Bipalium* is also remarkable, considering the many points in which these forms are closely allied.

A pair of large water-vascular trunks, or, as they are here termed, primitive vascular trunks, are conspicuous objects in transverse sections of the bodies of *Bipalium* and *Rhynchodemus*. A peculiar network of connective tissue is characteristic of these vascular canals on section, and is shown to present exactly similar features in *Leptoplana tremellaris*, *Dendrocœlum lacteum*, and *Bothriocephalus latus*. The close agreement in the relative position of the oviducts to the vascular canals in *Dendrocœlum* and our Land-Planarians is very remarkable. This primitive vascular system is homologous with the body-cavity present in the embryo leech and in *Branchiobdella* throughout life. It is not necessarily an excretory system, though the term water-vascular system has been generally considered to imply such a function for it. The nerves and ganglia of Planarians lie within the primitive vascular system, as do the corresponding structures within the primitive body-cavity of the leech.

Branches from the primitive vascular system in *Bipalium* possibly proceed to the ciliated sacs in the head, and perform an excretory function. A small marine Planarian was found to contain hæmoglobin. In *Bipalium* there are a series of separate testes disposed in pairs as in the leech. In *Rhynchodemus* the testicular cavities are more closely packed, and follow no such definite arrangement. The ovaries are simple sacs in both *Bipalium* and *Rhynchodemus*, and are placed very far forwards in the head, a long distance from the uterus. In *Bipalium* short branches given off from the

posterior portions of the oviduct are the rudiments of a ramified ovary, such as exists in *Dendrocœlum lacteum*. There are also glands present, which probably represent the yelk-glands and shell-making glands of aquatic Planarians in a more or less rudimentary condition. There is a comparatively simple penis and female receptive cavity in both *Bipalium* and *Rhynchodemus*. In *Bipalium* there is, further, a glandular cavity at the base of the penis (prostate). The organs described as nervous ganglia by BLANCHARD in *Polycladus* are almost certainly its testes and ovaries; and therefore the arrangement of these bodies in *Polycladus* is the same as that in *Bipalium*.

The chain of nervous ganglia described as existing in *Bipalium* (*Sphyrocephalus*) by SCHMARDA, and which has been referred to by so many authors, does not exist. There is no doubt that SCHMARDA mistook the ovaries and testes for ganglia. The real nervous system is ill-defined, but appears to consist of a network of fibres without ganglion-cells, which lies within the primitive vascular canals. In *Leptoplana tremellaris* the structure of the ganglionic masses is remarkably complex in the arrangement of the fibres; and well-defined ganglion-cells of various sizes are present and have a definite arrangement.

Numerous eye-spots are present in *Bipalium*, most of them being grouped in certain regions in the head, but some few being found all over the upper surface of the body, even down to the tail. The eye-spots appear to be formed by modification of single cells. In *Rhynchodemus* two eyes only are present. All gradations would appear to exist, between the simple unicellular eye-spot of *Bipalium* and the more complex eye of *Leptoplana* or *Geodesmus*, where the lens is split up into a series of rod-like bodies, forming apparently a stage towards the compound eyes of Articulata. It is quite probable that these compound eyes have arisen by such a splitting-up into separate elements of a single eye, and not by fusion of a group of unicellular eyes such as those of *Bipalium*. A peculiar papillary band runs along the lower portion of the margin of the head of *Bipalium*. The delicate papillæ are in the form of half cylinders, ranged vertically side by side. Between the upper extremities of the papillæ are the apertures of peculiar ciliated sacs. The papillæ, from the mode in which the animal makes use of them, are probably endowed with a special sense-function. The sacs may have a similar office, or they may be in connexion with the primitive vascular system, and have an excretory function; they may further be homologous with the ciliated tubes in Nemertines.

In considering the general anatomy of *Bipalium*, it is impossible to help being struck by the many points of resemblance between this animal and a leech. Mr. HERBERT SPENCER has, in his 'Principles of Biology,' placed a gulf between Planarians and Leeches by denoting the former as secondary, the latter as tertiary aggregates*. It is obvious, however, that a single leech is directly comparable to a single *Bipalium*. The successive pairs of testes, the position of the intromittent generative organs, the septa of the digestive tract, and, most of all, the pair of posterior cæca are evidently homolo-

* The idea is that an Annelid represents a series of Planarians, or corresponding secondary aggregates.

gous in the two animals. Further, were leeches really tertiary aggregates, the fact would surely come out in their development, or at least some indication of the mode of their genesis would survive in the development of some Annelid. Such, however, is not the case. The young worm or leech is at first unsegmented, like a Planarian; and the traces of segmentation appear subsequently in it, just as do the protovertebræ in vertebrates, which Mr. SPENCER calls secondary aggregates. If Mr. SPENCER'S hypothesis were correct, we should expect to find at least some Annelid developing its segments in the egg as a series of buds. It is not, of course, here meant to be concluded that Annelids are not sometimes in a condition of tertiary aggregation, as *Nais* certainly is when in a budding condition, but that ordinarily they are secondary and not tertiary aggregates; and if so, then so also are Arthropoda.

Much more information concerning the anatomy of Planarians will be required before it will be possible to trace the line of descent of *Bipalium* and *Rhynchodemus*, and determine what was the form of their aquatic ancestors. In the absence of accurate accounts of the structure of the American Land-Planarians, and even of the European *Rhynchodemus terrestris*, the question is very puzzling. The formation of either one of the two forms *Bipalium* or *Rhynchodemus* might be accounted for with comparative ease, from the arrangement of parts in the flat head of *Bipalium*. From the tree-like branching of the digestive tract in that region, the corresponding ramification of the vascular system, and general muscular arrangement, it might be imagined that *Bipalium* had come from a flattened parent of the common Planarian form, and that all the body except the head had become rounded and endowed with an ambulacral line. In nearly all points, except the eyes and the absence of branches to the oviduct, *Bipalium* seems more highly specialized than *Rhynchodemus*. We might imagine that *Rhynchodemus* and *Bipalium* had a common parent, and that when an ambulacral line was just beginning to be developed the two forms took different lines—*Rhynchodemus* losing all traces of the original flatness of its ancestor, and never developing any ciliated sacs or papillæ, but cherishing a single pair of large eyes at the expense of all the rest which it possessed, its testes, moreover, remaining in a comparatively primitive condition. But then comes the difficulty about the great difference in shape in the pharynxes of the two forms; and if it be suggested that, as is highly probable, several or many aquatic Planarians have taken to terrestrial habits, and that *Bipalium* has been derived from a form like *Leptoplana*, with a folded pharynx, whilst *Rhynchodemus* came from an ancestor with a tubular one, it is difficult to account for the many points of close resemblance between these two forms, and especially their similarity in external colouring, though this latter may perhaps be explained by mimicry. On the whole, it is evident that a close study of the anatomy of Land-Planarians cannot fail to lead to interesting results; and it is hoped that this memoir may lead to further work of the same kind. It would be of especial value to have a good account of the anatomy of *Geodesmus* and *Rhynchodemus sylvaticus*.

Description of the Plates.

PLATE X.

Fig. 1. *Bipalium Ceres*, sp. nov., of the natural size, from specimens preserved in absolute alcohol.

Fig. 2. Young of the same, from the same source.

Fig. 3. Young of *Bipalium Diana*, from specimens preserved in absolute alcohol, and of the natural size.

Fig. 4. *Rhynchodemus Thwaitesii*, sp. nov.

All four specimens from the Royal Botanic Gardens, Peradeniya, Ceylon; drawn of the exact dimensions.

Fig. 5. Vertical section of *Bipalium Diana*, taken in a direction transverse to the long axis of the body, at a spot about half an inch distant from the anterior margin of the animal's head. Drawn with a camera lucida.

The letter D, seen a little above the middle of the figure, is placed in the central digestive cavity, which in that portion of the body which is anterior to the entrance of the pharynx is single, as is ordinarily the case in Dendrocœlous Turbellaria. The cavities lettered D′ on either side of it represent the lateral diverticula which it gives off: as they are not given off quite at right angles to the central stem, they are not exposed in their entire length in a transverse section such as this. Between the letters D and D′ are seen portions of the septa which separate the successive diverticula and their branches from each other, and show decussating muscular fibres very plainly. The clear spaces (W) on either side the middle line, inferiorly to the origins of the lateral diverticula, are the two chief trunks of the water-vascular system, running antero-posteriorly, and are less stained with carmine than the rest of the section. The glandular masses (T) lying immediately exteriorly to them are the testes; in the interval between each testis and the water-vascular trunk is seen the *vas deferens* (V.D.) in section, and in the upper and outer angle of the water-vascular trunk is seen the oviduct (OD). The inferior surface of the body is flatter than the superior; but a considerable projection is formed along the middle line of the surface by an "ambulacral line" or "sole," whence these Turbellaria are sometimes termed "gasteropodous" (Diesing, *loc. cit.* p. 509). Where the ambulacral line rises above the level of the rest of the inferior surface of the body, cilia of large size are seen to clothe it. A zone of tissue, contrasting by its greater clearness with the cuticle and its basement membranes and muscles, runs round the whole body of the animal immediately internally to those structures. This greater clearness is due to the absence in this zone of the longitudinal layer of muscular fibres, which is largely developed both internally and externally to it. The area of the zone itself is

mainly occupied by radiating muscular fibres, prolongations of the circular muscles surrounding the viscera. It contains, interspersed in its substance, gland-cells containing rod-like bodies and pigment-cells. The longitudinal muscles, having been exposed in section to the action of carmine, are readily recognizable by the deep tint which they have taken, and may be seen to be specially developed (I. L. M.) along a line reaching to the region of the testes and water-vascular trunk of either side, from a point a little way internally to the lateral border of the animal. Opposite the lateral borders of the animal's body these muscles are sparingly developed; inferiorly, again, on either side, to the commencement of the intestinal diverticula, they are aggregated in considerable masses. The superficial muscular layers are largely developed along the median dorsal and infero-lateral lines. A collection of glandular tissue is seen on the outer side of either testis at X.

D. Central gastro-intestinal canal.
D'. Lateral diverticula given off from central canal, D.
E. Epidermis.
P. Pigment.
E. C. M. Exterior muscular layer, consisting of circular and decussating fibres.
E. L. M. External longitudinal muscular layer.
I. L. M. Internal longitudinal muscular layer.
L. M. External longitudinal muscular layer in the ambulacral line.
R. M. Zone occupied by radiating muscular fibres, and containing also glands, *Stäbchen-Organe*, and pigment-cells.
OD. Oviduct.
V. D. Vas deferens.
T. Testis.
W. Water-vascular trunk.
X. Aggregation of glandular cells.

Fig. 6. Vertical section of *Bipalium Ceres*, taken in a direction transverse to the long axis of the body, at a spot about half an inch distant from the anterior margin of the animal's head. Drawn with the camera lucida. The form of the body is seen to be very different from that of *B. Diana* (see fig. 5, Plate X.), and in some respects to approach that of *Rhynchodemus*. The points A, A correspond to the ridges characteristic of this species, which run along the body inferiorly on each side of the ambulacral line, and which contain masses of finely granular material, A, A, from which tracts of glandular matter lead to a point just above the testes. The ambulacral line projects less than in *Bipalium Diana*; the oviducts are lower in position than in that species, lying within the water-vascular trunks. The external circular and longitudinal muscular systems are greatly developed in the dorsal region.

A, A. Lateral glandular masses.
E. C. M. External circular muscular layer.
E. L. M. External longitudinal layer.
R. M. Radiating muscular fibres.
I. L. M. Internal longitudinal muscles.
E. Epidermis.
T. Testes.
OD. Oviduct.
W. Water-vascular space.
D. Central or gastro-intestinal canal.
D′. Lateral diverticula given off from central canal, D.

Fig. 7. Section transverse to the longer axis of the body of *Rhynchodemus Thwaitesii*, at a spot a little below the commencement of the series of testes. The ambulacral line does not in this case form a projection as in *B. Diana*; indeed the organ is here in a comparatively rudimentary condition, and does not possess the peculiar muscular arrangement described as existing in *Bipalium*; but its situation is marked by an entire absence of pigment in the part of the animal's body corresponding to it. These spots are seen on the superior surface (one median, two lateral), where there is a special concentration of dark pigment. These form the longitudinal dark stripes with which the animal's body is marked. A special development of the most external muscles may be observed here, as in *Bipalium Diana*, about the median dorsal and infero-lateral region, with a corresponding development of internal longitudinal fibres.

Only one of the diverticula (D) of the intestine is laid open, viz. that on the left side of the section. On the right side the septum is entire, and shows its decussating fibres. The water-vascular trunks (W) are seen to be connected by a transverse tract. The peculiar elongated glandular bodies, deeply stained, are seen to be abundant over an irregular arc around the testes on each side, and also just above the central digestive canal; at the lateral margins of the section some are seen passing towards the epidermis.

E. Epidermis.
E. L. M. External longitudinal muscles with external circular epidermis.
P. Pigment.
R. M. Radiating muscular fibres.
I. L. M. Internal longitudinal muscles.
T. Testis.
OD. Oviduct.
W. Water-vascular trunks.
X. Peculiar protoplasmic bodies.

Fig. 8. Central region of vertical section of *Dendrocœlum lacteum*, taken in a direction

transverse to the long axis of the body, at a spot just anterior to the mouth. Drawn with the camera lucida.

The section contrasts strongly with those displayed in figs. 5, 6, & 7, in being lengthened out from side to side, and having its superior and inferior surfaces irregularly parallel, owing to the flattened-out form of the Planarian from which it was prepared. The central digestive cavity D, with its diverticula D′, is more irregular in outline than in *Bipalium* and *Rhynchodemus*. The dark glandular masses (T, T) are seen scattered over the section, but in this particular one are exposed in greater abundance on the left side. The main trunks of the water-vascular system (W, W) are here, as in *Bipalium* and *Rhynchodemus*, rendered conspicuous by their being but slightly tinted with carmine. The oviducts are situate just above them, as also is the case in *Bipalium* and *Rhynchodemus*. A circular muscular coat succeeds the epithelial layer; and closely opposed to this are the longitudinal muscles of the body, in this animal not divisible into two systems, as in *Bipalium* and *Rhynchodemus*. The stout vertical fibres which run from one surface of the body correspond to the internal circular and radiating muscular fibres of the two Land-Planarians already figured. The small darkly stained masses partly internal to and partly mixed up with the longitudinal muscular fibres consist of urticating organs and small glandular masses, and some of them represent longitudinal muscular fibres exceptionally darkly stained.

D. Central gastro-intestinal canal.
D′. Lateral diverticula given off from central canal, D.
E. Epidermis.
E. C. M. External circular muscular layer.
L. M. Longitudinal muscular layer.
V. M. Vertical muscles.
OD. Oviducts.
T. Testis.
W. Water-vascular trunks.
X. Glandular masses.

Fig. 9. Three rod-like bodies from *Bipalium Diana* as they appear in sections from spirit-specimens, stained with carmine and mounted in dammar varnish.

Fig. 10. Epidermic structures from similar preparations.

A. Elongated irregularly shaped body often seen in the epidermis, deeply stained with carmine, and frequently in continuity with the glandular masses (G) represented in fig. 1, Plate XI.; probably masses of mucus hardened by alcohol in the act of their ejection from these glands.

B. One of the gland-cells (G. C.), fig. 4, Plate XI.

Fig. 11. From similar preparations, two parent cells of rod-like bodies; on the right a cell in transverse section, showing three chambers. Fig. 12. Fragments of similar cells.

Fig. 13. Small portion of a longitudinal section in the plane of the body of *Bipalium Diana* in the dorsal region, to show the muscular arrangement.

The appearance here represented is to be observed when a longitudinal section of *Bipalium* in the superficial dorsal region is viewed from above.

A. Superficial external circular and decussating muscular layer.

B. Stout longitudinal muscular bands seen beneath the external layer (A) by alteration of the focus of the microscope.

C. Urticating cells seen in section.

PLATE XI.

Fig. 1. Vertical section, taken in a direction transverse to the long axis of the body, of the skin of *Bipalium Diana* with the adjoining tissues, from the lateral margin of the animal in the region of the external generative opening. Drawn with the camera lucida from a specimen hardened in spirit. Highly magnified.

Superiorly is seen the epidermis (E), the structure of which is not well shown in this preparation; imbedded in it, however, are three of the peculiar rod-like bodies—Stäbchen-Körperchen. Beneath the epidermis lies the external circular muscular layer (E. C. M.), in this region (lateral) of the body not displaying that complex interlacement of fibres which is to be observed in it in the dorsal and inferior regions. A dark line separates this muscular layer from the epidermis, and indicates a narrow line deeply stained with carmine, which represents the basement membrane (B). Though this section is taken in the region of the external generative opening, an eye (O) is seen on the right-hand side. E. L. M. points to one of a row of longitudinal muscular bundles seen in section. Between the external circular muscular layer and the internal longitudinal muscles (I. L. M.) a layer of loose tissue intervenes, composed of fibres passing from the radiating muscles (R. M.) to the external circular muscular layer. In this loose tissue are imbedded the glandular masses (G), the branching pigment-bodies (P), and the parent glands of the rod-like bodies (RG).

E. Epidermis.

B. Basement membrane.

E. C. M. External circular muscular layer.

O. Eye.

E. L. M. External longitudinal muscles.

I. L. M. Internal longitudinal muscles.

R. M. Radiating muscles.

G. Glandular masses.

P. Pigment-bodies.

RG. Parent glands of the rod-like bodies.

Fig. 2. Corresponding section to that shown in fig. 1, from *Rhynchodemus Thwaitesii*; also drawn with the camera lucida.

The epidermis (E) shows a vertical striation, and contains four cells with rod-like bodies in them. The external muscular coat (E. C. M.) is very thin; between the external (E. L. M.) and the internal longitudinal muscles (I. L. M.), and closely opposed to these latter, a band of internal circular muscular fibres is developed, being formed of a special development of the radiating muscles (R. M.) in this region of the body (see fig. 7, Plate X.). The parent glands of the rod-like bodies are less shrivelled by the action of spirit than in the foregoing preparation.

E. Epithelial layer.
R. Cell containing rod-like bodies.
E. C. M. External circular muscular layer.
E. L. M. External longitudinal muscles.
G. Glandular mass.
RG. Parent glands of rod-like bodies.
I. C. M. Internal circular muscular band.
I. L. M. Internal longitudinal muscles.
R. M. Radiating muscles.

Fig. 3. Vertical section transverse to the longer axis of the body through half the ambulacral line of *Bipalium Diana*, with the immediately adjoining region included. The side of the ambulacral line is seen to be clothed with long and strong cilia, which, however, fade off and almost disappear to the right and left in the direction of the general body-integument and in that of the actual inferior surface of the ambulacral line severally. The epithelial layer is seen to change its character entirely as it approaches the region where it bears the strong cilia, being there thicker and entirely free from intermixture with rod-like bodies; on the inferior surface of the ambulacral line it is very thin indeed. The external circular and decussating muscular layer is seen to split into two portions—one of which is continued as a thin layer over the ambulacral line immediately externally to the external longitudinal muscles of that organ; whilst the other, passing inwards horizontally, separates off a series of smaller muscular bundles from the main body of external longitudinal muscles, and then spreads its fibres out fanwise to become lost among the general muscular mass of the ambulacral line. Strong vertical fibres are seen to descend and end in club-shaped extremities between the external longitudinal muscular bundles of the ambulacral line. These are specially developed radiating fibres.

C. Cilia.
E. Epithelial layer.
E. C. M. External circular muscles.

x 2

E. L. M. External longitudinal muscles.

L. M. External longitudinal muscles of the ambulacral line.

R. M. Radiating muscles.

V. M. Vertical muscles of the ambulacral line.

I. L. M. Internal longitudinal muscles.

Fig. 4. Portion of the epidermis of *Bipalium Diana* in vertical section. From a section of a specimen hardened in spirit, treated with caustic-potash solution.

The epidermic structures in a state of contraction from the action of the spirit have been swollen out again by the potash. The rod-like bodies (R, R) are here of an elongated oval form; each is enclosed with a capsule. They vary in size, and are placed at different altitudes in the epidermis. The large irregularly oval cells (G., G. C.), filled with granular contents, are glandular elements of the epidermis. The remainder of the epidermis is made up of stout fibres, probably remnants of empty capsules of rod-like bodies. Beneath the epidermis and external circular muscular coat (E. C. M.) is seen a gland-capsule (RG) with a rod-like body contained in it. The capsule sends a process up to the epidermis.

Fig. 5. Schematic representation of the arrangement of the fibres of the external circular and decussating muscular layer of *Bipalium Diana* in vertical section, as seen in its extreme development in the dorsal region.

A. Decussating fibres.

B. Circular fibres.

C. Longitudinal muscular bands in section.

Fig. 6. Diagrammatic representation of the generative organs of *Bipalium Diana*, as seen when laid open by longitudinal section. The external generative orifice (EX.) leads into a ciliated cavity: into this cavity opens superiorly the common internal generative aperture (CG.). A straight ciliated tube, the vagina, passes vertically from this aperture, and turning sharply at right angles terminates at the entrance of the oviducts (OD.). The horizontal portion may be considered to be the uterus. Into the lower extremity of the vagina posteriorly opens the cavity containing the penis (C. P.), at an angle of about 45°. The dark lines radiating from the muscular body containing the uterus and vagina are accessory glands.

EX. External generative orifice.

CG. Common internal orifice.

V. Vagina.

UT. Uterus.

OD. Oviduct.

C. M. Circular muscular coat.

L. M. Longitudinal muscular coat.

C. P. Cavity containing penis.

P. Penis.
PR. Prostate.
V. D. Vas deferens.

Fig. 7. Diagrammatic section of the generative organs of *Rhynchodemus Thwaitesii*. The penis is seen contained in its spacious special cavity communicating by a narrow channel with a small cavity common to itself and the uterus, which cavity again communicates by a narrow opening with a third cavity, which opens into the external generative orifice. The pair of oviducts unite into a single tube, which passes up the back of the uterus to open near its summit. The muscular fibres and epithelium of the uterus are greatly thickened at its summit, forming a square-shaped projection into its cavity; this probably disappears when the uterus is distended either by ova or (to judge from the analogy of freshwater Planarians) by a capsule containing several ova, and is most likely due to the action of spirit.

EX. External generative orifice.
V. Vagina.
C. P. Canal for penis.
UT. Uterus.
D. E. Ductus ejaculatorius.
P. Penis.
A. R. Azygos receptaculum seminis.
V. D. Vas deferens.
OD. Oviduct.
T. Testis.

Fig. 8. Terminal segment of generative organs of *Bipalium Diana*, enlarged five diameters. Beneath are seen the organs intact, above the same opened by vertical section. The rounded mass on the left contains the vagina and uterus, the elongated oval body on the right the penis. The capsules of the two bodies are intimately united, and the cavity containing the penis communicates exteriorly with an aperture common to it and the vagina.

U. Uterus.
Pr. Prostate.
P. Penis.
ex. External generative aperture.
OD. Oviduct.
V. D. Vas deferens.

Fig. 9. Portion of a vertical section transverse to the long axis of the body of *Bipalium Diana*, passing through the external generative orifice. The cavity containing the penis is seen to open by a small aperture into the vagina. Above is the uterus, which turns off at right angles from the vagina.

EX. External generative orifice.

CG. Common internal generative opening.
V. Vagina.
C. P. Minute opening of the cavity containing the penis.
U. Uterus.
C. M. Its circular muscular coat.
L. M. Its longitudinal muscles.
A, A. Accessory glands.

PLATE XII.

Fig. 1. Diagrammatic representation of the positions and relative proportions of the organs of *Bipalium Diana* in the anterior portion of the body, as seen from beneath, enlarged two diameters. The digestive tube (D) is represented only in front of the pharynx, and its diverticula only at the most anterior portion of the body. In the peculiar cheese-knife-shaped extremity the digestive tube is seen to ramify in an arborescent manner. The ovaries (OV.) lie just behind the angle formed by the union of the broad head with the body, and their long ducts (OD.), attached to them on their exterior aspect, pass down the body, coming into close contact with the sheath of the pharynx, and crossing the vasa deferentia (V. D.), and making a sharp turn inwards, pass into the uterus (UT.). Between the angle formed by this sharp turn and the pharynx some short branches, which slope backwards and outwards, join the oviducts.

The testes (T, T) commence a short distance behind the ovaries, and are slightly external to them in position. There are about twenty-four pairs of them. They communicate with a pair of ducts (V. D.), which, skirting the sheath of the pharynx and here coming into close relation with the oviduct, pass to the inner side of the latter, and turning sharply backwards upon these lines, enter the sheath of the penis (S. P.).

D. Digestive tube.
M. Mouth.
O. Opening of pharynx into digestive tube.
OV. Ovaries.
OD. Oviduct.
T, T. Testes.
V. D. Vas deferens.
S. P. Sheath of penis.
UT. Uterus.
EX. External generative aperture.

Fig. 2. Posterior extremity of *Bipalium Diana* as seen when dissected under spirit, viewed from beneath, magnified two diameters. At the part of the body which lies in front of the oral apparatus the digestive tube (*d*) is seen to be single. At

the point (O) it divides into two, which pass one on each side of the sheath of the pharynx, and from this point backwards to the very extremity of the body the digestive tube is double. A stout median septum intervenes between the two tubes in the posterior part of the body, and being prolonged upwards splits, as it were, into two to form the investing sheath of the generative organs (G) and the pharynx (PH.). Just above the pharynx and below the generative organs, on the left-hand side of the drawing, are seen indicated the openings of the lateral diverticula into the main digestive tubes. The peculiarly elongated pharynx (PH.) communicates with the tube by the small aperture (O). The small oval mass consists of the penis and uterus with their immediate investments.

d. Digestive tube.
PH. Pharynx.
O. Opening of pharynx into digestive tube.
G. Small mass containing penis and uterus.

Fig. 3. Diagram representing the various organs, their relative positions and dimensions, of *Rhynchodemus Thwaitesii*, supposed to be seen from beneath, enlarged four diameters. Though the anterior extremity of the body is considerably broader than the posterior, the body is seen to run more abruptly to a point at the anterior than at the posterior extremity, a sort of shoulder being formed at the point where the sides of the body bend inwards to form its apex.

This difference of form between the two extremities is always marked in specimens preserved in spirits. The digestive tract in the anterior part of the body exists as a single median tube, with a series of lateral cæca or diverticula opening into it on either side; these are indicated by the faint transverse lines, as is also their arrangement at the anterior and posterior extremities of the body. The median tube divides into two, to pass on each side of the capsule of the tubular pharynx, and remains double henceforth, embracing the capsule of the generative organs in like manner. Anteriorly is seen the single pair of eyes. The penis is represented as opened by horizontal section. The oviducts are observed to pass from the inner sides of the ovaries.

E. Eyes.
OV. Ovaries.
D. Digestive tract.
T. Testis.
OD. Oviduct.
O. Opening of pharynx into digestive tract.
M. Indicates position of mouth.
PH. Pharynx.
A. R. Azygous seminal reservoir.

V. D. Contorted vas deferens.
P. Penis, with seminal canal displayed.
C. P. Cavity through which the penis is protruded.
EX. External generative aperture.
UT. Uterus.

Fig. 4. Blind extremity of the uterus of *Bipalium Diana*, and entrance into it of the oviducts, as seen in a vertical section transverse to the long axis of the body, and slightly anterior in position to the one from which fig. 6 is taken.

The internal muscular coat here does not preserve its circular disposition. The fibres composing it pass inwards with the oviducts, inferiorly mingling with some fibres accompanying these ducts. The oviducts pass inwards to meet one another in the middle line of the body; they, however, do not anastomose, but open into the cavity of the uterus by separate orifices (O), which are divided from one another by a slight ridge or projection. The blind termination of the uterine cavity (U) is seen here in the contracted state. The epithelial lining of the uterus is very thick, and probably glandular in function; it is covered with long cilia.

R. M. Radiating muscular fibres.
L. M. Longitudinal muscular fibres seen in section.
C. M. Circular muscular fibres.
OD. Oviduct.
O. Opening of oviduct into uterus.
U. Blind extremity of uterus.
E. Epithelium.

Fig. 5. Vertical section, transverse to the long axis of the body, of the penis and its immediate surroundings in its basal region, from *Bipalium Diana*. Drawn with the camera. The base of the penis is here seen in section; superiorly it is seen attached to the body by a mass of muscular fibres, which converge towards it and unite with its proper muscular system. This mass of muscular fibres is part of that which is seen passing into the penis in fig. 1, Plate XIII.: the fibres composing it radiate towards the penis in all directions, and are thus exposed in both longitudinal and vertical sections of the body; they become in great part longitudinal muscles of the penis (L.P.), which are especially developed on its dorsum, as seen in the section, but partly also join the radiating and circular muscular systems of that organ. On its inferior aspect the penis, where free in its cavity or sheath, is provided with delicate special longitudinal (L. M.) and circular (C. M.) muscular fibres. The penis, as here seen in section, is seen to consist of from without inwards, first, a layer of epithelium (*a*), which appears as if composed of small rounded transparent vesicles; then a thin layer of external circular muscular fibres (E.C.), which superiorly are lost amongst the vertical

fibres entering the organ; then longitudinal fibres only just visible inferiorly as small black dots (Ep.), but largely developed on the dorsum of the penis (L. P.); then a series of stout radiating fibres (R. M.), with what resembles water-vascular spaces (S) in their interstices, and which are sections of muscles similar to those (W) seen to pass into the penis superiorly between the masses of longitudinal muscles (L. P.). Succeeding these radiating fibres we find a stout and compact ring of internal circular muscular fibres (I. C.), succeeded by the prostatic glandular tissue (Pr.). Compare figs. 1 & 2, Plate XIII.

C. Sheath of penis.
E. Epithelium of cavity of sheath of penis.
C. M. Its circular muscular coat.
L. M. Its longitudinal muscles.
R. f. Radiating fibres attaching it to the surrounding tissue, *i. e.* here the septum between the two intestinal canals.
a. Epithelium of penis.
E. C. External circular muscular coat of that organ.
L. P. Longitudinal muscles of same in section.
R. M. Its radiating muscles.
S. Retractor muscles in section.
W. Retractor muscles in longitudinal section.
I. C. Internal circular muscular coat.
Pr. Prostate gland.

Fig. 6. Transverse section of the uterus of *Bipalium Diana*. The external longitudinal muscular coat is omitted. Externally is seen the circular muscular coat (C. M.), formed of densely interlaced fibres; then internally to this the stroma (S), composed of small spindle-cells and fibres, succeeded by the ciliated epithelium (E). The line of demarcation between the epithelium and the stroma is, however, often not well marked. The cavity of the uterus in its contracted state is cruciform in transverse section.

C. M. Circular muscles.
S. Stroma.
E. Epithelium.

Fig. 7. Portion of the longitudinal muscles of the vagina from the same preparation, highly magnified, to show how the accessory gland-tissue breaks up into fine twigs which ramify amongst the muscular fibres.

A. Accessory gland-tissue.
L. M. Longitudinal muscular fibres of the vagina.

Fig. 8. Section of the pharynx of *Rhynchodemus Thwaitesii*, taken in a direction transverse to its longer axis. Drawn with the camera lucida.

In the centre is the tubular cavity of the pharynx, clothed with a layer of epithelium, which appears as a narrow light zone. Immediately externally

to this zone is a broader zone darkly shaded, as being deeply stained with carmine, and consisting of dense circular muscular fibres. Externally to this the black dots represent a zone of longitudinal muscular fibres seen in section. Following on this is a broad zone occupied by loose radiating fibres, then two irregular darkish lines, corresponding with a large quantity of glandular matter present in this region, and some slight circular fibres, succeeded by a zone (A) occupied by fine dots, representing longitudinal muscular fibres in section, which fibres lie in meshes formed by radiating and circular fibres. The structure of the extreme verge will best be comprehended by reference to fig. 9, in which this is represented much enlarged.

A. Muscular zone referred to in the description of fig. 9.

Fig. 9. Portion of the periphery of the foregoing section, much enlarged. Drawn with the camera. To the right hand is seen the external epithelium of the pharynx. A light line (A) follows this to the left, representing an apparently structureless membrane, succeeded by a single row of very stout muscular fibres (L. m). The remainder of the drawing represents the broad muscular zone (A) of the last figure, which is here seen to consist of a meshwork of radiating and circular fibres, in the interstices of which are stout longitudinal fibres in section. The circular fibres are more densely aggregated at the outer margin of the zone, and form a sort of special zone (*i. c. m.*).

e. Epithelium.

A. Structureless layer.

L. m. Longitudinal muscular layer.

i. c. m. Circular muscular layer.

PLATE XIII.

Fig. 1. Penis of *Bipalium Diana* within its proper cavity or sheath, as exposed in a longitudinal section and in the plane of the body; drawn with the camera. The penis (*p*) is seen to be conical in form; it is bent upon itself. Towards its pointed extremity may be seen the termination of its central canal, lettered *d*. Strong muscular fibres are seen passing into the organ from above to form its longitudinal muscular system; between the interlacement of these fibres are spaces (*s*) which are lightly stained in carmine preparations, and are transverse sections of branched retractor muscles of the penis.

The external circular fibres of the penis are faintly indicated.

C. Cavity of sheath of penis.

p. Penis.

d. Spermatic duct.

s. Branched retractor muscles seen in transverse section.

u. The same muscles seen in their longitudinal section.

a. Vesicular epithelium clothing the base of the penis.

c. m. Circular muscles of the sheath of the penis.

e. Its irregular epithelial lining.

Fig. 2. Longitudinal section in the plane of the body, through the muscular bulb at the base of the penis. Drawn with the camera.

The rounded muscular mass here seen is that from which the penis takes its origin, and the fibres seen passing into the penis in fig. 1, Plate XIII., are portions of this muscular bulb. The fibres of the bulb are continuous externally with those of the sheath of the penis, internally with those of the penis itself. The oval fissure in the middle, which stands out in relief as very slightly tinged with carmine, is the prostate cavity nearly filled with glandular substance. The retractor muscles (*u*) are seen passing inwards, and appear to join the septa between the glandular crypts of the prostate, as in fig. 3.

c. Cavity of sheath of penis.

e. Epithelium of the sheath.

em. Its circular muscular coat.

m. Muscular mass of bulb of penis.

u. Retractor muscles.

I. C. Internal circular muscular coat.

Po. Glandular substance of prostate.

Fig. 3. Small portion of the innermost region of a transverse section of the base of the penis of *Bipalium Diana*, magnified. Drawn with the camera.

The retractor muscles (W, W) are seen passing inwards between the bundles of longitudinal muscular fibres (L.P., L.P., L.P.), traversing the dense internal circular muscular ring (I. C.), and forming a network in the space which intervenes between the internal circular muscles and the glandular prostatic tissue (Pr.). The actual termination of the retractor muscles was not determined, but they often have the appearance of becoming continuous with the glandular bodies (Pr.).

I. C. Internal muscular layer of penis.

Pr. Glandular prostatic tissue.

L. P. Longitudinal muscles of the penis.

W, W. Branched retractor muscles.

C. M. Scattered circular muscular fibres.

Fig. 4. Testis of *Bipalium Diana* in a plane parallel to the inferior surface of the body. A section of the organ is seen to be circular in outline. The organ is enclosed in a capsule consisting of an outer layer of loose tissue with large open spaces in it, and an inner layer of compact tissue. There is an opening in the capsule laterally, where the interior cavity of the gland becomes continuous with that of its ducts, and its epithelium is thickened opposite the point of entrance into it of the duct from each testis. The duct is narrower

immediately above the junction with the testis. The contents of the testis-cavity divide themselves into two regions—an outer, where the formation of the larger spermatic cells takes place, and an inner, where the cells ripen and the spermatozoa are formed. The tails of the spermatozoa are seen turned towards the outlet.

E. External layer of capsule.
I. Internal ditto.
D. Duct.
G. External region with smaller cells.
C. Internal with larger cells and spermatozoa in process of formation.
m. Longitudinal muscular fibres of the body.

Fig. 5. Testis of same animal, which has discharged its contents and collapsed, lowly magnified. An internal membrane has parted from the capsule, and is seen folded up in the anterior.

Fig. 6. Spermatozoa of *R. Thwaitesii* in process of development.

Fig. 7. Sections of vas deferens of *Bipalium Diana*, highly magnified.

Fig. 8. Longitudinal section in the plane of the body of the ovary of *Bipalium Diana*, from various chromic acid and alcohol preparations. The ovary, which is thus seen in section, has an oval outline, and is crowded with ova in various stages of development. The oviduct, with its funnel-shaped expansion and ciliated epithelium, is seen passing up on the right-hand side of the ovary in the drawing. The exact manner of its connexion with the ovary was not ascertained in this species, but is probably similar to that in *Rhynchodemus* (see fig. 13). In *Bipalium Diana* the duct was not traced further than is represented in the drawing It enters on the most external side of the ovary—that is, the side which is furthest from the median line of the body. Immediately exteriorly to the oviduct is seen the small yelk-gland attached to the ovary by a pedicle, which is probably its duct. This gland was present in the condition here represented only in one specimen examined; in the remainder it was quite rudimentary. In the ovary there is a special aggregation of immature ova at the summit. Some stroma-fibres with fusiform cells are seen to pass between the more mature ova. The organ has a compact inner tunic, which is succeeded externally by a loose fibrous investment. The whole lies imbedded between the internal longitudinal muscles, some fibres of which are seen on each side of it in the drawing.

a. Outer loose fibrous investment of ovary.
b. Inner denser ditto.
c. Immature ova.
d. Mature ova.
e. Stroma-cells.
f. Longitudinal muscular fibres.

g. Yelk-gland.
h. Mass of small cells.
od. Oviduct.

Fig. 9. Longitudinal section of oviduct of *Bipalium Diana* in the region of the external generative organs. A short lateral branch tube is seen to enter the duct at an inclination which slopes towards the posterior extremity of the body. The short branch is clothed with cilia, which are directed towards the opening into the oviduct. Attached to the extremity of the branch are stroma-fibres and fusiform cells, which appear to form branched spaces in the body-substance. The branch enters at the external side of the oviduct. The cilia of the oviduct are seen here, as elsewhere, to be direced towards the termination of the duct. The duct has a distinct basement membrane.

a. Anterior extremity of segment.
d. Stroma and fusiform cells.
e. Basement membrane of branch entering oviduct.

Fig. 10. Transverse section of oviduct of *B. Diana*, magnified about twice as much as in foregoing. The basement membrane is well seen. The cilia appear to have a spiral arrangement.

Fig. 11. Epithelial lining of ovary.

Fig. 12. Series of stages in the development of ova. The youngest ova cannot be distinguished from the lining cells of the ovary. The germinal vesicle enlarges rapidly to its full size; it then loses its finely granular appearance and becomes quite clear and transparent. The investing yelk-mass continues to increase in size after the germinal vesicle has ceased growing. The last stage in its development is the appearance of large oil-globules in its substance. The external capsule, which is seen to invest the more mature ova, is derived from the stroma of the ovary. A clear space is seen between the ovum and this capsule.

Fig. 13. Longitudinal section of ovary of *Rhynchodemus Thwaitesii* in the plane of the body. From several preparations. The ovary is seen to be circular in outline. The oviduct passes up on the right-hand side of the figure, which corresponds to the internal side of the ovary. Where the duct joins the ovary there is a mass of fusiform cells, which forms a papillary projection into the cavity of that organ. From this projection stroma-fibres radiate out between the ova. The ovary has two investments, as in *Bipalium Diana*. Immature ova are seen all round the margin of the cavity. The mature ova occupy a central position.

a. Outer loose fibrous investment of ovary.
b. Inner denser ditto.
c. Immature ova.
d. Mature ova.
e. Stroma.

h. Mass of cells and terminal papilla.

o. oviduct.

Fig. 14. Transverse section of oviduct of *R. Thwaitesii*.

Fig. 15. Longitudinal section in a plane parallel to the ambulacral surface of *Rhynchodemus Thwaitesii* in the region of the testes. The section passes through the main water-vascular space and the testes. These organs stand out in relief, being not so deeply stained as the surrounding tissue. The dark tissue on the right-hand side of the drawing consists of muscles; that on the left of glandular matter, which is present in great quantity in this situation, immediately externally to the testes, all through the anterior part of the body. The testes (T) are seen as irregularly oval bodies closely packed against one another. The water-vascular trunk, in which some very faint longitudinal fibres may be traced, gives off transverse branches, which are seen as white lines on a dark ground: these are very numerous on the right side amongst the muscular tissue; on the left side beyond the testes, amongst the glandular tissue, only three are to be seen.

Fig. 16. Edge of the anterior semilunar extremity of *Bipalium Diana*, as seen by reflected light, magnified. The edge of the anterior extremity or head is seen to be traversed vertically by deep indentations or sulci; these are caused by contraction, due to the action of spirit, but have been described as characteristic of certain species. This peculiar mode of contraction is probably, however, connected with the power which the animals possess during life of throwing out tentacular-like projections from this portion of their body. The edge of the head is seen to be marked out into several bands. The superior broad band (*a*) is somewhat darkly pigmented; it is succeeded inferiorly by a lighter unpigmented band marked by a fine line, *b*. At *d* is seen a row of semicylindrical papillary projections, between which, at their upper extremities, is seen a row of black dots (*c*), which indicate the apertures of a series of ciliated pits; the row of papillæ is succeeded by an unpigmented band.

f, *f*. Deep indentations of anterior margin.

a. Broad pigmented band containing eyes.

b. Fine line.

c. Row of openings of ciliated pits.

d. Row of papillary projections.

e. Unpigmented band.

Fig. 17. The papillæ of *Bipalium Diana*, shown in the preceding figure at *d*, as viewed from the side, and more highly magnified.

A. Position of the openings of the ciliated pits, lettered *c* in the preceding figure. Compare Plate XIV. fig. 8.

PLATE XIV.

Fig. 1. Portion of vertical section transverse to the long axis of the body of *Leptoplana tremellaris*. Drawn with the camera lucida. The section from which the drawing was made was cut nearly from the centre of the body of a specimen hardened in spirit. The portion here represented lies just to one side of the cavity containing the pharynx inferiorly. A portion of the water-vascular trunk (W) is seen in section. The external circular muscular coat (E. C. M.) is regarded by KEFERSTEIN (*l. c.* p. 17) merely as a basement membrane; it is, however, obviously homologous with the external circular muscular coat of *Bipalium* and *Rhynchodemus*.

E. C. M. External circular muscular coat.
E. L. M. External longitudinal muscular coat.
I. C. M. Internal circular muscles.
I. L. M. Internal longitudinal muscles.
V. M. Vertical muscles.

Fig. 2. Transverse section of main water-vascular trunk of *Bothriocephalus latus*, copied from 'Beiträge zur Anatomie der Plattwürmer,' SOMMER und LANDOIS (Leipzig, 1872), Taf. iv. fig. 1, *k*, querdurchschnittenes Seitengefäss, for comparison with fig. 1.

Fig. 3. Portion of a section taken in a direction transverse to the longer axis of the body of *Bipalium Diana* through the broadest part of the anterior semilunar extremity—that is, as it is from A to B in fig. 4. Since the digestive tract in this portion of the body spreads out in an arborescent manner, it is here seen cut through in a series of places (D, D, D). The spaces are arranged, as far as the drawing shows, symmetrically on each side of a central space (D′), which is the direct continuation of the main median digestive tube of the fore part of the body. The lateral offsets are cut more and more obliquely as they are more and more distant from D′, so that the outermost appears as an elongated space. Surrounding the median portion of the digestive tract is a large quantity of densely stained tissue, mainly glandular, which sends offsets downwards across the broad light space, which is the water-vascular space (W). The glandular tissue also spreads out laterally between the branches of the digestive tract and the water-vascular space. The water-vascular space stretches out to the margin of the head in the region of B, which points to two of the peculiar papilliform bodies which form a row along the whole anterior margin of the animal, and between which are the ciliated pits. The water-vascular space is traversed by a few stout vertical fibres and a number of fine horizontal fibres. A group of eyes is seen at E, on the margin of the animal's semilunar extremity. Superiorly a large number of eyes are seen lying just beneath the epidermis, and also some pigment spots, P. At A,

immediately above the median digestive space, is a region devoid of eyes and pigment, which corresponds to a light stripe in this situation in the living animal. The ambulacral line is not seen here, the section being taken in front of its termination. The muscular fibres are seen to decussate as they spread out from the median line towards the periphery, both above and below the region occupied by the digestive tract and water-vascular space.

A. Space in median line of body devoid of pigment and eyes.
B. Peculiar papillæ.
E. Groups of eyes.
P. Pigment.
W. Water-vascular space.

Fig. 4. Longitudinal section in the plane of the body of the anterior extremity of *Bipalium Ceres*, passing through the main water-vascular trunks. Drawn with the camera lucida.

The preparation from which the drawing is taken was made from a specimen hardened in alcohol, and the section was stained with carmine. The water-vascular spaces are very slightly stained, and thus stand out in relief. Between the two main water-vascular trunks (W, W) is seen a dark elongated mass, which terminates anteriorly in a pointed extremity. This mass is composed of muscles of the ambulacral line, and mainly of vertical fibres. The two water-vascular trunks pass up into the head, and there ramify and anastomose with one another in all directions, or rather form one large sinus divided up more or less into radiating channels by the vertical muscular fibres of the head, which appear in the drawing as dark dots.

A. Left lateral border of anterior extremity.
B. Right lateral border.
W, W. Main water-vascular trunks.
A. L. Muscles of ambulacral line.
E, E. Eye-spots.
D. Terminations of the diverticula of the digestive tract laid open, the specimen from which the section was taken having been slightly contorted by contraction in spirit.

Fig. 5. Longitudinal section in the plane of the body of *Rhynchodemus Thwaitesii*, passing through the main water-vascular trunks at their anterior extremity. The pair of water-vascular trunks (W, W) are separated by a dark mass composed of the muscles of the ambulacral line; they do not ramify at their extremities, but end bluntly. At the anterior extremity of the body are seen the eyes (E, E) *in situ*.

A. L. Ambulacral line.
W, W. Main water-vascular trunks.
E, E. Eyes.

Fig. 6. Small portion of the main water-vascular trunk of *Bipalium Diana*, as seen in vertical section. Drawn with the camera. Three muscular bands are seen traversing the portion of the water-vascular trunk here represented, and they are crossed diagonally by several finer muscular fibres. The interstices between these two sets of fibres are filled with a close network of very fine fibres, bearing here and there small nuclei. The darkly stained irregularly shaped masses (X, X) send out finely ramifying processes, which become lost amongst the fine fibres forming the general meshwork, and apparently anastomose with them.

V. M. Vertical muscular fibres.

D. M. Diagonal ditto.

X, X. Irregular protoplasmic bodies.

Fig. 7. Main trunk of the water-vascular system of *Dendrocœlum lacteum* in vertical section, with adjoining tissue, from a section corresponding to that represented in fig. 8, Plate X., but more highly magnified. Drawn with the camera.

The water-vascular trunk (W), which is here divided into two by a stout vertical muscular fibre, is seen to be filled with a network of extremely fine fibres, some of which have minute nuclei upon them. The open spaces in the meshwork are irregularly oval. The oviduct (OD.) immediately above the external portion of the water-vascular trunk is seen to be made up of definite nucleated cells, as in *Bipalium* and *Rhynchodemus*; it is imbedded in a mass of fusiform cells and stroma. The vertical muscular fibres (V. M.) pass downwards between the longitudinal muscles (L. M.), and unite with the circular muscles (C. M.).

V. M. Vertical muscular fibres.

OD. Oviduct.

W. Water-vascular system.

L. M. Longitudinal muscles.

C. M. Circular muscles.

E. Epithelium.

Fig. 8. The papillæ of *Bipalium Diana*, as seen in a thin section shaved off from the anterior margin of the animal's head, and viewed directly from the front, and magnified more highly still. Compare Plate XIII. fig. 17.

A. Openings of the ciliated pits between the upper extremities of the semicolumnar projections, of which four are here displayed.

PLATE XV.

Figs. 1, 2, 3, 4. Series of longitudinal sections in the plane of the body through the cephalic ganglionic masses of a Sea-Planarian, *Leptoplana tremellaris*, from a specimen preserved in spirit; drawn with the camera lucida. The series, as

numbered, commences from above. The distinctness and variety in size of the ganglionic cells is to be noted, also their disposition in a bilaterally symmetrical manner, and the complex arrangement of nerve-fibres passing between the several regions.

A pair of accumulations of especially large cells (A, A) is to be observed (posterior aspect of the ganglionic masses) in figs. 1 & 2. The nerve-cells are disposed mainly at the periphery of the ganglionic mass, the central region being occupied by commissural fibres; but a small aggregation of cells is seen amongst the commissural fibres at B. Well-defined transverse commissural fibres (C, C) connect the two halves of the ganglionic mass anteriorly and posteriorly. Connecting fibres run between the roots of the different nerves at the periphery of the central portion of the ganglionic mass. The central region is occupied by vertical fibres, here seen in section as dark specks: these vertical fibres are especially developed at D.

Fig. 5. Portion of the network of the nervous system from the head of *Bipalium Proserpina*, as seen in a longitudinal section in the plane of the body, from a specimen hardened in chromic acid. Drawn with the camera lucida.

The network here represented comes into view in sections prepared from specimens hardened in chromic acid when these sections are stained with carmine, and conforms in position and ramification with the water-vascular system. Masses of finely granular matter are seen imbedded amongst the fibres at the nodes of the network.

Fig. 6. One of the eye-spots of *Bipalium Diana*. The eye consists of a hollow cell of the shape here represented, the wall of which is pigmented posteriorly, but transparent anteriorly. There is a sharp line of demarcation between the transparent anterior and pigmented posterior portion. The pigment is present in the form of small rounded granules. An unpigmented spot appears to indicate a nucleus.

Fig. 7 shows a section of the eye. The cell-cavity is seen to contain a lens-like body, here dark as stained with carmine. A highly refracting substance exists between this lens-like body and the pigmented wall of the cell.

Fig. 8. Eye of *Rhynchodemus Thwaitesii*. The anterior transparent cornea projects through the epithelial layer of the animal's body. A short filament is seen attached to the proximal extremity of the eye.

Fig. 9. Small portion of the margin of a longitudinal section in the plane of the body of *Bipalium Diana*, from the region of the body just posterior to the semilunar anterior expansion. Drawn with the camera lucida. Superiorly is seen the epithelial layer (E), beneath which is the basement membrane (B) and the external circular muscular fibres (E. C. M.), here seen in transverse section; internally to these is the external longitudinal muscular layer (E. L. M.), here rather thin, and beneath these are the eyes (O).

This longitudinal section allows the basement membrane to be clearly distinguished from the external circular muscular layer. In transverse sections they nearly always appear fused.

Fig. 10. Ideal section of the eye of *Leptoplana tremellaris*.

C. Cornea.

L. Lens made up of rod-like bodies with rounded nucleus.

Ch. Choroid.

R. Retina.

V. Highly refracting transparent substance.

Fig. 11. The same preparation as the one figured Plate XIV. fig. 8, seen when focused, so as to render visible a deeper stratum. The mouths of the ciliated pits (A) are seen to be oval in form, and to have a very distinct lining, which is dotted with cilia.

Fig. 12. Papillæ from the anterior margin of the head of *Bipalium Proserpina*, from a section similar to that from which the preceding figure was drawn. The papillæ are of much the same form as those of *Bipalium Diana*, but the mouths of the ciliated pits (A) are of a more rounded form.

Fig. 13. Longitudinal section in the plane of the body of *Bipalium Diana* through the ciliated pits. Drawn with the camera. Slightly stained spaces appear to run to the pits; between the light spaces is a peculiar tissue formed of small spindle-shaped cells.

Fig. 14. Section of the glandular lining of the digestive tract of *Planaria torva*, from a transverse section of the animal's body. Drawn with the camera lucida. Made from an alcoholic preparation.

Fig. 15. Section of the glandular lining of the digestive tract of *Bipalium Diana*, from a transverse section of a specimen hardened in chromic acid. Drawn with the camera lucida. From the region of the mouth.