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A FURTHER REPORT ON PARASITIC NEMATODES IN THE COLLECTION OF THE ZOOLOGICAL SURVEY OF INDIA.[1]

By H. A. BAYLIS, *M.A.*, *D.Sc.*, *British Museum* (*Natural History*), *and*
R. DAUBNEY, *M.Sc.*, *M.R.C.V.S.*, *Ministry of Agriculture and Fisheries.*

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The greater part of the nematode collection of the Zoological Survey has been reported upon in a former publication (Baylis and Daubney, 1922). When this report had already been sent to India for publication, a further consignment of material was received. This had been partly worked out by Major F. H. Stewart, I.M.S., and had been sent to him after his return to England, in order that he might complete his investigations.

Major Stewart, hearing that we had been working at other material belonging to the Zoological Survey, very generously offered to hand over to us the specimens in his possession, together with his manuscript notes and many excellent drawings, which he was kind enough to place unreservedly at our disposal.

It so happens that many of the little-known species studied in India by Major Stewart have been fairly fully redescribed by other workers in the meanwhile, and it is not considered necessary to publish new descriptions of them in this paper. In the case of certain species which still stood in need of better description, we have made free use of the information supplied by Major Stewart's notes, and have reproduced some of his figures. In such cases the origin of the descriptions and figures is indicated in the text.

A few forms received later from the Zoological Survey are included in this report.

The number of new forms in the present collection is small. Three new species, including one which has been made the type of a new genus, have already been briefly described in a short note (Baylis and Daubney, 1923), and fuller descriptions of them, with figures, are given here. Several species, some of which were described in the former report, occur again in this collection. In some cases they are recorded from new hosts.

As in the earlier report, the names used for Indian host-animals are those given in the *Fauna of British India* (1888-1898).

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[1] The first report appeared in *Mem. Ind. Mus.* VII, 4 (1922).

Superfamily ASCAROIDEA Railliet and Henry, 1915.

Family *ASCARIDAE* Cobbold, 1864.

Subfamily Ascarinae Travassos, 1913.

Genus **Ascaris** L., 1758.

Ascaris equorum Goeze, 1782.

The collection includes two males of this species collected from horses on different occasions, and in addition a single female *Ascaris* having the general appearance of *A. equorum*, labelled as "from the intestines of cattle." This specimen differs greatly in appearance from those which we have regarded as *Ascaris vitulorum* (see Baylis and Daubney, 1922), although in the light of recent work by others (Boulenger, (1922); Macfie, (1922)) it seems not impossible that two forms have at different times been confused under this name.

There are a few references in literature to the occurrence of *Ascaris equorum* (*A. megalocephala*) in cattle, but the matter is one that needs further investigation.

Genus **Belascaris** Leiper, 1907.

Belascaris mystax (Zeder, 1800).

Material from the tiger and leopard is included in the collection.

Belascaris marginata (Rud., 1802).

This species is represented by a few specimens (three sets) from dogs.

Genus **Toxascaris** Leiper, 1907.

Toxascaris leonina (v. Linst., 1902).

One set of specimens, " vomited by a lion."

Toxascaris transfuga (Rud., 1819) Baylis and Daubney, 1922.

From a bear (*Ursus* sp.).

Genus **Ophidascaris** Baylis, 1921.

Ophidascaris filaria (Duj., 1845).

Several sets of specimens from *Python molurus*, *P. reticulatus* and *Python* sp., including two batches of immature forms from the lung of *P. molurus*.

Ophidascaris naiae (Gedoelst, 1916).

(Figs. 1, 2.)

In our former paper (Baylis and Daubney, 1922) we referred to this species material from *Naja tripudians* and from *Bungarus fasciatus*, but did not attempt to describe it. The present collection also includes a few specimens from *Naja tripudians*, *Bungarus bungaroides* and *B.*

fasciatus. Those from *Naja tripudians*, collected at Sara Ghat, are in fairly good condition, but do not attain quite the full size given by Gedoelst (1916). They include one male, two females and some immature forms. The rest of the material is in rather poor condition, and will not be specially considered.

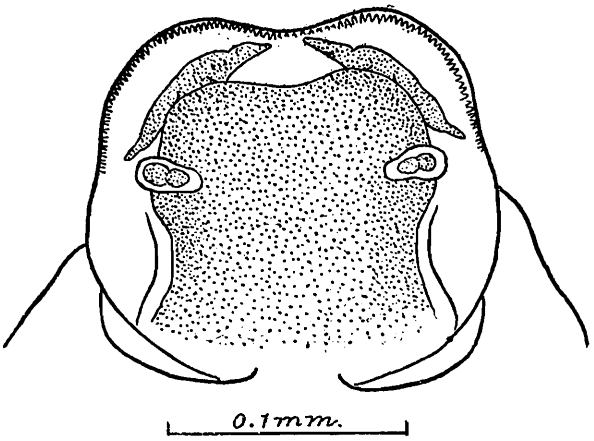

Fig. 1.—*Ophidascaris naiae*. Dorsal lip of female; external aspect. (Original.)

It is difficult to be certain of the specific determination, owing to the absence of sufficiently precise characters from the original description, and the absence of figures.

The number of postanal papillae in the male agrees with Gedoelst's account, and their arrangement in our male specimen is indicated in fig. 2. The three nearest to the tip of the tail on either side form a triangle, two being lateral or subdorsal, the third very small and subventral. A little more anteriorly there are two ventral pairs, and at the sides of the cloacal aperture, somewhat widely separated from the rest, a pair of very large papillae, apparently having double terminations.

The spicules in this specimen measure 3·25 mm. and 4·3 mm. respectively, the longer being that of the left side. (Gedoelst gives 4·64 mm. and 5·04 mm.).

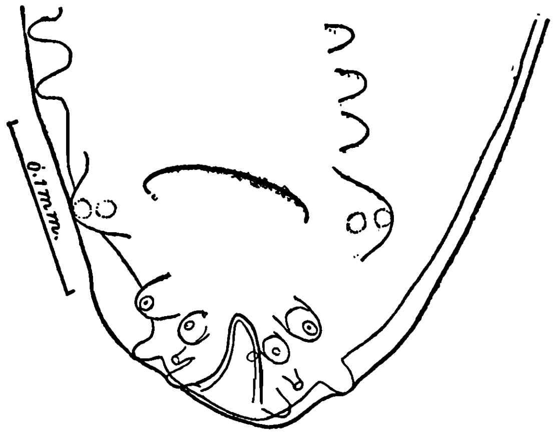

Fig. 2.—*Ophidascaris naiae*. Caudal end of male; ventral view. (Original.)

The oesophagus may attain a length of 3·25 mm. or more in the female (Gedoelst gives 2·9 mm.). The structure of the lips, in our material, is characteristic (fig. 1). The pulp sends out two forwardly and inwardly directed lobes, each of which is prolonged in opposite directions into two points, one running forward and towards the middle line of the lip, the other backward and towards the margin. Radiating processes have not been seen on these lobes, but apart from this they are very similar to those of *Ophidascaris filaria.*

The vulva is considerably behind the middle of the body. In a specimen just under 51 mm. long, it was situated at 21·7 mm. from the posterior end. The vagina is long, narrow and sinuous, and passes gradually into the unpaired portion of the uterus. This and the two branches of the uterus are very short. The latter, after a sinuous course occupying about 10 mm. in the 51 mm. specimen, pass suddenly into short, narrow, muscular canals, and these again into the wider oviducts. The coils of the ovarian tubes extend backward to about 4 mm. from the posterior end and forward to the level of the vulva.

Ophidascaris sp.

Taken from the stomach of *Tropidonotus piscator* on two occasions, once in the Botanical Gardens, Calcutta, and once by Col. F. Wall, I.M.S., at Dibrugarh, Assam. The material is in very poor condition, and we are unable to determine it with certainty. It may possibly be *O. gestri* (Parona, 1890).

Genus **Polydelphis** Duj., 1845.

Polydelphis anoura Duj., 1845.

(Figs. 3, 4.)

Host. *Python molurus.* Localities: Nepal Terai; Kichha, Naini Tal District.

The material from Kichha consists of very numerous examples of both sexes. These, being in a somewhat macerated condition, enable certain details to be easily made out which, in better-preserved material, have hitherto escaped notice.

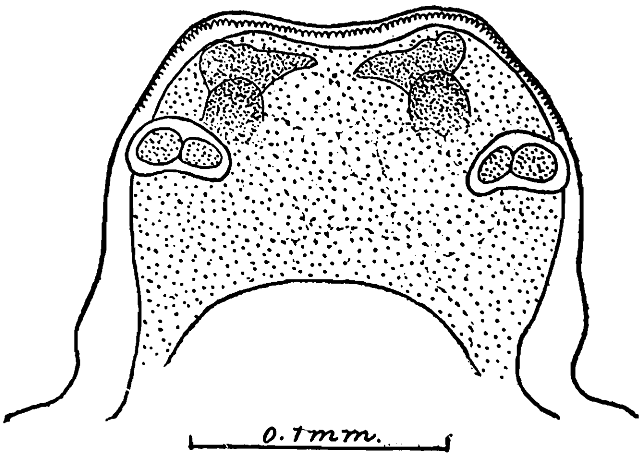

FIG. 3.—*Polydelphis anoura.* Dorsal lip of male; external aspect. (Original.)

In a former paper one of us (Baylis, 1921) summarized the existing descriptions of this species and added a few original observations, but the only male example then available for examination could not be referred with certainty to the species, and was therefore disregarded. The statement that there were only two pairs of postanal papillae in the male was quoted from other authors. In the light of the present material this statement is clearly seen to be incorrect. As the accompanying figure (fig. 4) shows, there are six pairs of postanal papillae, of which the most anterior pair consists of large double papillae, situated near the corners of the cloacal aperture. As is commonly the case in this group, the three pairs nearest to the extremity of the tail are so arranged as to form a triangle of three papillae on each side. Between these and the large double papillae there are two pairs situated ventrally. In addition to the usual row of preanal papillae on each side of the ventral surface, there is a median preanal papilla with double terminations.

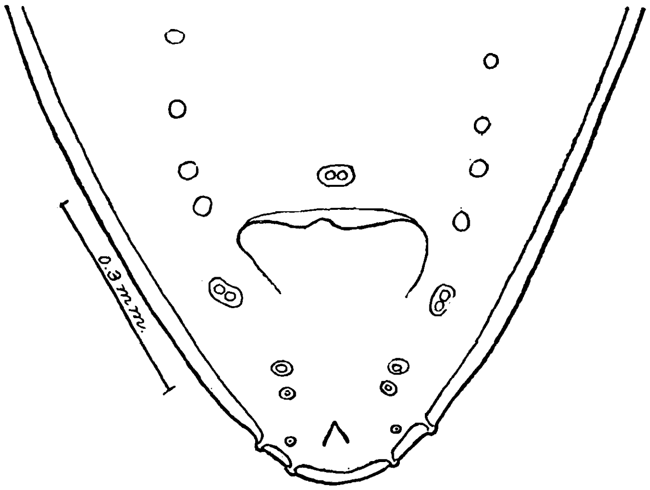

Fig. 4.—*Polydelphis anoura.* Caudal end of male ; ventral view. (Original.)

The lips also require further notice. They are somewhat emarginate, and not straight, in front. The pulp of each lip sends out two inwardly and forwardly directed processes, with flattened and expanded terminations. The expanded portion has somewhat the outline of a human foot. Radiating processes on its border are either absent or very hard to detect. The lip therefore somewhat resembles in structure that of *P. oculata,* as figured by v. Linstow (1899, fig. 7). On re-examining other material, previously determined as *P. anoura,* from *Python molurus* and also from an African python, the same processes of the pulp were recognised, and they may therefore be regarded as a constant specific character.

Polydelphis quadricornis (Wedl, 1862).

Two specimens " from gut of snakes," Katagum, N. Nigeria, presented to the Indian Museum by Dr. J. H. Ashworth, are referred to this species.

Polydelphis sewelli Baylis and Daubney, 1922.

This species, originally recorded by us from *Coelopeltis monspessulana* from Palestine, appears to be represented in the present collection by material from *Tropidonotus stolatus* from Lakhimpore, Assam, and from *Tropidonotus piscator* from Dibrugarh, Assam, in both cases collected by Col. F. Wall, I.M.S. Specimens collected on two occasions from *Bungarus fasciatus*, in one case by Col. Wall at Dibrugarh, though not determinable with certainty, are probably also referable to the same species.

Polydelphis sp.

Two male individuals, from the stomach of *Lachesis* (*Trimeresurus*) *gramineus*, collected by Col. F. Wall, I.M.S. Determination uncertain.

Subfamily ANISAKINAE Raill. and Henry, 1912, *emend.* Baylis, 1920.

Genus **Porrocaecum** Railliet and Henry, 1912.

Porrocaecum angusticolle (Molin, 1860).

This species, redescribed by us in our former paper from material taken from *Milvus govinda*, is here represented by some female specimens from the intestine of a vulture, collected by Mr. T. Southwell at Satpara, Chilka Lake, Orissa.

Porrocaecum sp.

A number of larval forms from the mesentery of a fish, *Otolithus maculatus*, collected by Mr. I. H. Burkill.

Genus **Contracaecum** Raill. and Henry, 1912.

Contracaecum spiculigerum (Rud., 1809).

Some specimens of this species were collected from the little cormorant (*Phalacrocorax javanicus*) by Dr. S. L. Hora at Samal Island, Lake Chilka.

Contracaecum microcephalum (Rud., 1809).

Taken from a pond heron (*Ardeola grayi*) by Dr. S. L. Hora at Samal Island, Lake Chilka.

Contracaecum haliaëti, nom. nov.

Syn. *C.* (*Ascaris*) *aquillae* (Smith, Fox and White, 1908) Baylis, 1923.

Three females, corresponding with the description of *Ascaris aquillae* given by Smith, Fox and White (1908), were taken from the upper part of the intestine of a white-bellied sea-eagle (*Haliaëtus leucogaster*) at Barkuda Island, Lake Chilka.

The name *aquillae* is presumably a *lapsus* for *aquilae*, and the combination *Ascaris aquilae* was used by Gmelin in 1790 for another worm. Consequently it becomes necessary to rename the species described by Smith, Fox and White. It appears not impossible that this is identical with the *Ascaris ceylanica* described by v. Linstow (1904) from *Haliastur* and *Poliaëtus* in Ceylon. From the figure of the head v. Linstow's species would appear to be probably a *Contracaecum*, but the description is so brief that we are unable to identify the species with certainty with *A. aquillae,* and have therefore thought it advisable to give the latter an entirely new name.

Contracaecum lobulatum (Schneider, 1866).

(Fig. 5.)

Host. Gangetic dolphin (*Platanista gangetica*) (stomach and mouth). 5 sets of material. Locality (when given), River Hughli, near Calcutta.

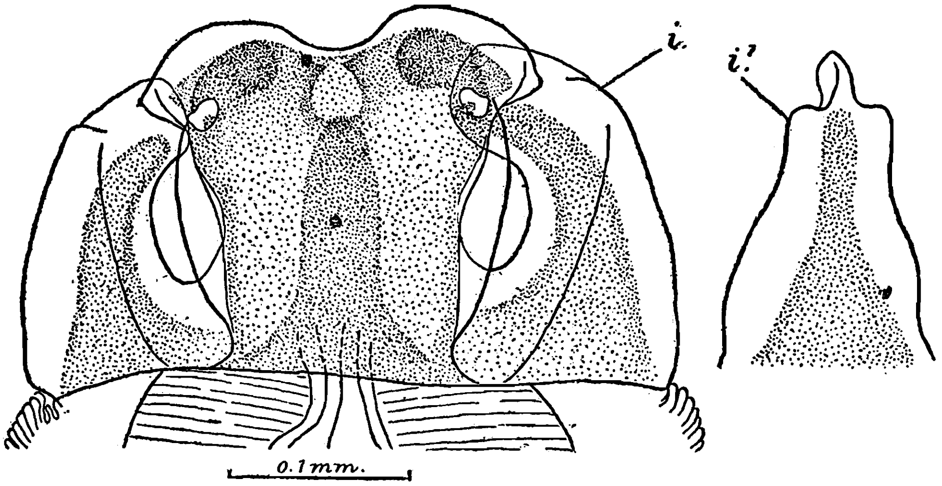

Fig. 5.—*Contracaecum lobulatum.* Head of female; dorsal view. *i.* interlabium, in profile; *i'.* external aspect of same. (Original.)

The abundant material of this species in the collection is unfortunately all in rather poor condition. We refrain from attemping a full new description, but give a new figure of the head (fig. 5). The existing literature dealing with the species is rather scattered. Schneider (1866) gives a very short diagnosis, with a figure of the tail of the male, showing the number and arrangement of the papillae. Krabbe (1878) gives a figure of the head, which fails to bring out the important features clearly, and no description. Jägerskiöld ((1893) and (1894)) describes little of the anatomy except the presence of an excretory organ like that of typical species of *Contracaecum,* and the structure of the alimentary canal and its appendages, which are figured. v. Linstow (1907) gives a description based on Indian Museum material. This description is fuller than that of Schneider, but it is necessary to consult Schneider and Jägerskiöld as well in order to obtain a fairly complete account of the species.

The figure of the lip given by v. Linstow is quite misleading. The wing-like structures shown on either side may be intended to represent the interlabia, but, if so, give an entirely wrong idea of their shape. In reality the interlabia (fig. 5, *i* ,*i'*) are nearly as long as the lips. Each has its free end compressed into a narrow cuticular flange and curved inwards between two of the lips. A distinct " shoulder " is formed at the point where the compression takes place. The pulp of the dorsal lip has its two main anterior lobes separated by a deep " saddle " on the inner side. Each of these lobes also gives rise to a rounded accessory lobe which projects inwards and downwards when the lip is viewed from the dorsal surface. We can add nothing to Schneider's description of the caudal papillae of the male, except that the arrangement of the postanal papillae is very irregular, and that the preanal series contains only about seven pairs.

The name *lobulatum* is retained for this species on account of the uncertainty as to its identity with *Ascaris delphini* Rud., 1819. The material referred to and named *A. delphini* by Rudolphi was originally recorded from the same host as *C. lobulatum* by Lebeck in 1801. Except for the indication of the host, and the expression "*pollicares,*" *A. delphini* Rud. is a *nomen nudum,* and Stiles and Hassall (1899) very properly take the view that, although possibly the same as *A. lobulata,* the species is not identifiable. By other authors (Diesing, Stossich) *A. delphini* has been regarded as a synonym of *A. simplex* Rud., and should this be correct it must belong to the genus *Anisakis,* which differs greatly from *Contracaecum.*

Larval forms of *Contracaecum.*

The collection includes larvae of one or more species of this genus from the peritoneum of the following fishes :—

Barilius bola. Localities, Tharai River; Gandak River, Saran, N. Bengal.
Callichrous pabda. Locality, Lucknow.
Wallago attu. Locality, Lucknow.
Cyprinus carpio. Locality, Soochow, China.

The material from *Callichrous* and *Wallago* is part of that referred to by Stewart (1914, p. 179) under the numbers L. 33 and L. 36.

Genus **Dujardinia** Gedoelst, 1916.

Dujardinia halicoris (Owen, 1833).

(Figs. 6, 7.)

From intestine of dugong (*Halicore dugong*) (three specimens, in poor condition).

This species has been described in considerable detail by Parona (1889) and by v. Linstow (1906, *a* and *b*). We have only a few slight additions and corrections to make to the existing descriptions, basing our remarks not on the material in the present collection, but on Indian specimens in the British Museum.

There is a well-marked constriction separating the head from the neck (figs. 6, 7). Contrary to the statement of v. Linstow, well developed interlabia are present. They are broad and rounded externally, and bluntly conical at their free ends, which converge towards the axis between the bases of the lips. v. Linstow's figures of the dorsal lip give a rather misleading impression of its shape, this being probably due to tilting and consequent foreshortening. It is almost octagonal in outline. The two small anterior processes of the pulp are conical, and project forwards and inwards. The dorsal lip has two moderately large, simple papillae. The pulp of each ventro-lateral lip is asymmetrical, the ventral lobe being relatively short and carrying a large, double papilla ; the lateral lobe long, with a very small papilla at its extremity. Though dentigerous ridges are absent, the broad cuticular margins of the lips are folded and produced internally into a series of large, tooth-like projections, usually bilobed. The excretory pore is situated at about 1·2—1·3 mm., and a pair of small cervical papillae, buried in the cuticle, at about 1·4—1·5 mm., from the anterior extremity.

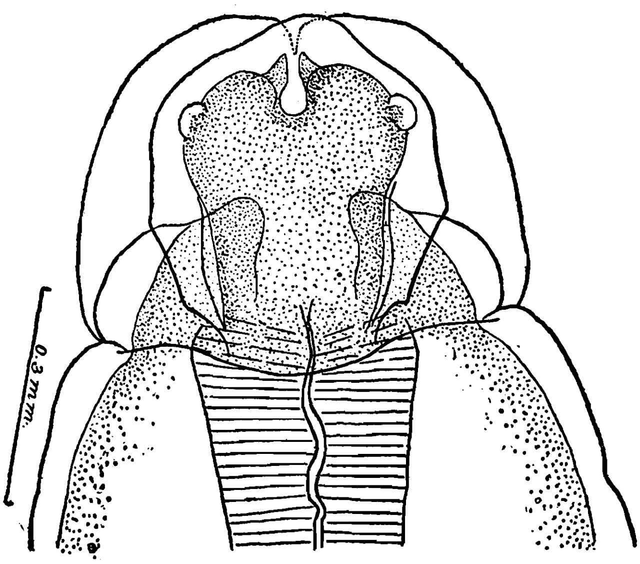

FIG. 6.—*Dujardinia halicoris.* Head of male; dorsal view. (Original.)

The caudal papillae of the male are remarkably few. Parona stated the number as five pairs, while v. Linstow gives seven pairs, of which three are said to be postanal and four preanal. We agree with v. Linstow as to the number of preanal papillae, but find that in the position of his most anterior pair of postanals there are usually two distinct papillae on either side, one close behind the other. In one of the specimens examined, however, while there were two papillae on the left side, only one could be found on the right. The number of papillae seems, therefore, to be normally eight pairs. The spicules are described and figured by v. Linstow as simple rods with a rounded knob at the

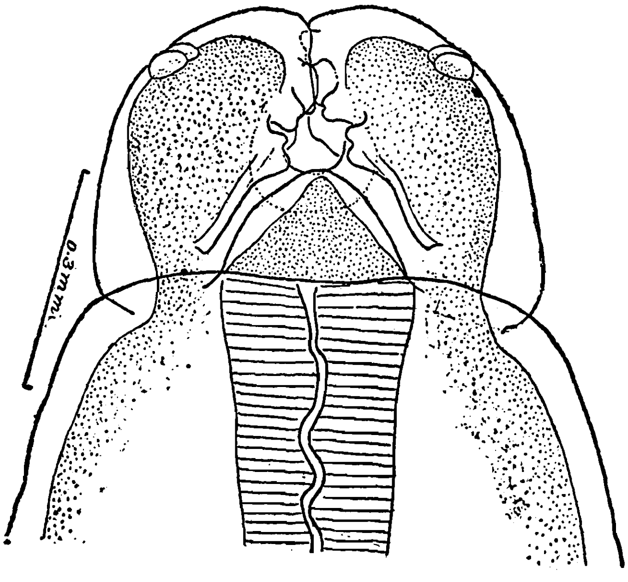

FIG. 7.—*Dujardinia halicoris.* Head of male; ventral view. (Original.)

proximal extremity. We find that each spicule has a tubular shaft, expanded into a funnel at the proximal end, and a pair of alae, broad distally and much inrolled on the ventral side of the spicule. The spicules measure only 1·1 mm. in length.

The two authors quoted give the position of the vulva correctly as about one-third of the total length from the anterior end. Baird (1859) gave it erroneously as two-thirds. Parona describes and figures the oviducts as arranged in zig-zags. In the female specimens examined by us it is a striking feature that the oviducts, which turn forward immediately from the posterior ends of the uterine branches, run with an almost straight course, parallel to the latter, as far as the level of the vulva, where they become lost in the close transverse loops of the ovarian tubes.

The systematic position of this species is somewhat uncertain. It differs from the form which we regard as *Dujardinia helicina* (Molin), the type of the genus, in having very short spicules and no accessory piece, but agrees with it in the structure of the alimentary canal and other characters (see Baylis (1920) ; also Baylis and Daubney (1922)).

Larval *Anisakinae.*

Encapsuled larval forms of species either of *Porrocaecum* or *Anisakis* occur in the collection from

(*a*) the deep-sea fish, *Dysalotus alcocki* (body-cavity). Marine Survey, Station 315, 705 fathoms.

(*b*) *Callichrous padba* or *Wallago attu.* (Part of " L. 33 " of Stewart (1914), p. 179.) These specimens were sorted out from among the material mentioned above under *Contracaecum.* The form to which Stewart's description applies is evidently the *Contracaecum.*

Larval *Ascaridae.*

(*a*) Two specimens from *Uroconger lepturus,* taken at a depth of 200 fathoms, are in too poor a condition to be assigned to any genus.

(*b*) A number of specimens, encapsuled in the subcutaneous tissue of the brown musk shrew (*Crocidura murina*). Locality, Trivandrum. The material had unfortunately been desiccated, but was restored by means of 1 per cent. saline, followed by a glycerine and alcohol mixture. The worms are of considerable size, and apparently cannot be identified with *Ascaris incisa* Rud., which occurs in shrews and is considered to be the larva of *Porrocaecum depressum* (Zed.) The structure of the alimentary canal was not clearly made out, and it is uncertain whether there is a ventriculus or not. We are unable, therefore, to determine the genus to which the worms belong.

Family *HETERAKIDAE* Raill. and Henry, 1914.

Subfamily HETERAKINAE Raill. and Henry, 1912.

Genus **Ascaridia** Duj., 1845.

Ascaridia perspicillum (Rud., 1803).

From intestine of domestic fowl, Calcutta.

Ascaridia columbae (Gmel., 1790).

From a pigeon, Zoological Garden, Calcutta.

Genus **Strongyluris** A. Müller, 1894.

Strongyluris calotis Baylis and Daubney, 1923.

(Figs. 8, 9.)

Baylis and Daubney (1923), p. 334.

Host: *Calotes nigrilabris.* Position : rectum. Locality : Pattipola, Ceylon.

The male of this species measures 8·9—11·1 mm. in length and 0·4—0·5 mm. in maximum thickness ; the female 11—13·65 mm. and 0·55—0·75 mm. respectively. The diameter of the head is 0·06—0·08 mm. Each lip (fig. 8) has broad lateral cuticular expansions and a further cuticular flange projecting anteriorly. The dorsal lip carries two large marginal papillae, the ventro-lateral lips each one papilla, situated further from the margin and towards the ventral side. The neck is wider than the head forming a " shoulder " behind the base of the lips. A second " shoulder " is formed a little further back by the commencement of a cuticular inflation which covers part of the pharyngeal and oesophageal regions. The cuticular striations are exceedingly fine. The lateral fields are of the type usual in the genus. No cervical papillae have been seen, nor any rows of papillae on the body. The alimentary canal shows the structure characteristic of *Strongyluris.*

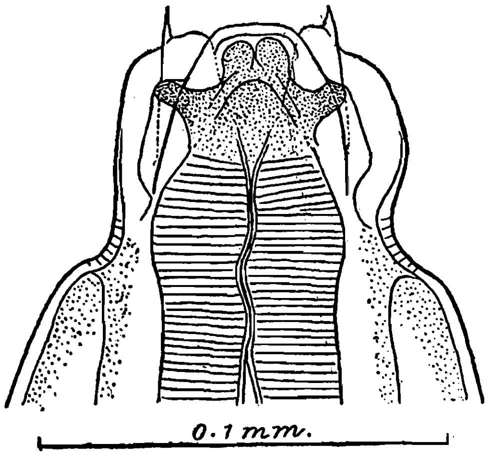

Fig. 8.—*Strongyluris calotis.* Head of female ; dorsal view. (Original.)

The distance from the anterior end of the head to the end of the " pharynx " is about 0·26—0·3 mm., and from the same point to the end of the oesophagus, including the bulb, 1·75—2·25 mm. The bulb measures 0·25—0·3 mm. in length and 0·28—0·35 mm. in diameter. The intestine is very wide for a short distance from its junction with the oesophagus, and then becomes very narrow until a short distance before the rectum, where it widens out again into an expanded bulb. The nerve-ring is situated at 0·5—0·55 mm., and the excretory pore at 1·1—1·45 mm., from the anterior end.

The tail, in both sexes, has a minute terminal spike. In the male the tail measures 0·1—0·12 mm. in length. The caudal end is obliquely truncate, but so abruptly as to appear as if cut off almost at right angles to the longitudinal axis of the body. The sucker and the cloaca thus open almost posteriorly. The sucker is of unusual relative depth, its chitinous wall measuring 0·12—0·16 mm. in depth and 0·14—0·17 mm.

in outside diameter. The spicules are subequal, 0·75—0·8 mm. in length, the left being slightly longer than the right. They are simple, tapering tubes, with a maximum diameter of about 0·03 mm., and covered externally with coarse granulations. There appears to be no accessory piece. There are ten pairs of caudal papillae, the arrangement of which can best be indicated by means of a figure (fig. 9). Of the three papillae nearest to the tip of the tail on each side, one is quite lateral, with a long peduncle; one subventral, sessile; and one slightly more lateral than the last-mentioned, very small and slender. Altogether seven pairs may be described as postanal, the remaining three being situated at the sides of the sucker, with a gradual decrease in size from behind forwards.

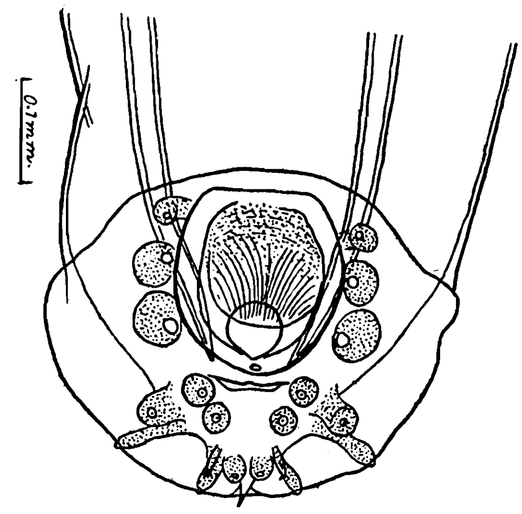

FIG. 9.—*Strongyluris calotis.* Caudal end of male; ventral view. (Original.)

In the female the tail is very short (0·2—0·25 mm). and bluntly rounded behind, with the exception of the little terminal spike. There is a pair of caudal papillae at 0·05 mm. from the tip. The vulva is a transverse slit with rather prominent lips, situated at 4·7—5·65 mm. from the posterior end of the body. The vagina runs forward for a short distance from the aperture, and then turns back upon itself to run posteriorly. The arrangement of the rest of the female organs is that usual in the genus. The eggs are oblong-oval in shape, and of the usual type, with a thick shell. They measure 0·0875—0·0975 mm. × 0·05—0·0525 mm., and when ready for laying contain an embryo which is just beginning to elongate.

Genus **Spinicauda** Travassos, 1920.

Spinicauda sp. (?)

A few immature specimens, in bad condition, from the duodenum of (?) *Lyriocephalus scutatus* (the knob-nosed lizard of Ceylon). No locality mentioned. We are unable to determine the species. As has already been pointed out by one of us (Baylis, 1923 *a*), the genus *Sonsinia*, proposed in our earlier report, falls into synonymy, its species being the same as those of *Spinicauda.*

Family *OXYURIDAE* Cobbold, 1864.

Genus **Oxyuris** Rud., 1803.

Oxyuris equi (Schrank, 1788).

A number of female specimens from a horse. Locality, Lahore.

Genus **Enterobius** Leach, in Baird, 1853.

Enterobius vermicularis (L., 1758).

Two sets of specimens from man.

Genus **Crossocephalus** Railliet, 1909.

Crossocephalus brevicaudatus Baylis and Daubney, 1923.

Baylis and Daubney (1923), p. 333.

Host: Indian rhinoceros (*Rhinoceros indicus*). Position: stomach Locality: Nepal terai, India.

This species was collected in company with a large number of specimens of *Kiluluma stylosa* and a single female referred to *Necator americanus*. The material consists of three females only.

The specimens measure from 5·3 to 6·2 mm. in length and up to 0·4 mm. in maximum thickness. The head has the usual characteristics of the genus. It is furnished with three pairs of armed jaws, and a pair of very prominent ear-like papillae on the cuticular collar. No cervical papillae have been seen. The oesophagus is from 0·945 to 0·955 mm. long. The excretory pore is situated at 1·22 to 1·35 mm. from the anterior end. Its lips are surrounded by a prominent, wrinkled, cuticular swelling, and connected with the pore is an ovoid bladder measuring about 0·13 mm. × 0·08 mm.

The tail is short and blunt, measuring about 0·25 mm. The vulva is situated about 0·13 mm. in front of the anus. The uterus contains from six to eight embryos, varying in size according to the degree of their development, but extremely large in the later stages.

In the absence of males the differentiation of this form from other species of *Crossocephalus* depends entirely upon measurements. In total length the specimens are distinctly shorter than females of *C. longicaudatus* Baylis, from *Rhinoceros sumatrensis*, but are well within the range of the measurements given by Gedoelst (1916) and by v. Linstow (1899) for *C. viviparus*, from the zebra. The excretory pore is situated much nearer to the anterior end in *C. brevicaudatus* than in either of the other species mentioned, while the tail of the female is less than half the length of that of *C. viviparus* and only about one-seventh of that of *C. longicaudatus*. For convenience the tabulated measurements of *C. viviparus* and *C. longicaudatus* given by Baylis (1919) are here reproduced, together with the measurements of *C. brevicaudatus* and of *C. zebrae* Yorke and Southwell. The last species is regarded by Yorke and Southwell (1920) as distinct from *C. viviparus*, chiefly on the ground of the supposed difference in the position of the vulva. The position, however, assigned to the vulva of *C. viviparus* by v. Linstow was, we feel confident, erroneous, and we are inclined to regard *C. zebrae* as a synonym of *C. viviparus*. If the measurements of *C. viviparus* given by v. Linstow and by Gedoelst be compared, it will be evident that the species has a considerable range of variation in size, and the measurements of *C. zebrae* on the whole fall between the extremes.

	brevicaudatus	*longicaudatus*		*viviparus* [v. Linst.]		*viviparus* [Gedoelst]	*zebrae*	
	♀	♂	♀	♂	♀	♀	♂	♀
Length	5·3—6·2	7·0	9-10	6·32	6·76	5·5—9·5	7·6—8·3	7·4—9·4
Thickness (max.)	0·4	0·5	0·63	0·43	0·55	0·28—0·512	0·44	0·498
Oesophagus, length	0·945-0·955	1·0	1·0	[1·02]	[0·9]	1—1·15	1·002—1·02	1·016—1·085
Tail, length	0·25	0·25—0·3	1·7—1·9	[0·26]	[0·55]	0·575	..	0·488—0·617
Spicules, length	..	0·44, 0·24	..	0·35, 0·26	..	..	0·295—0·353, 0·145—0·176	..
Vulva, distance from anus.	0·13	..	(?	..	2·34	0·192—0·208	..	0·17—0·255
Excretory pore, distance from anterior end.	1·22-1·35	less than 2·0.	2·0	close behind oesophagus.		1·9—2·2	2·027—2·172	1·866—2·11.

Family *KATHLANIDAE* Travassos, 1918.

Genus **Zanclophorus** Baylis and Daubney, 1922.

Zanclophorus kempi Baylis and Daubney, 1922.

This species is represented by a single young female specimen from the type host, *Testudo elongata.*

Superfamily FILARIOIDEA Weinland, 1858.

Family *FILARIIDAE* Claus, 1885.

Subfamily FILARIINAE Stiles, 1907.

Genus **Acanthocheilonema** Cobbold, 1870.

Acanthocheilonema evansi (Lewis, 1882).

(Figs. 10, 11.)

Filaria evansi Lewis, 1882.

The material consists of one female and a portion of a male taken from the spermatic artery of a camel at Lahore, Punjab.

The female specimen measures about 210 mm. in length and 0·73 mm. in maximum thickness. The available portion of the male, which consists of about 15 mm. of the posterior end, indicates that the male is very much more slender.

The body of the female tapers gradually from the middle to the head and tail, and more abruptly in the first half-millimetre from the head and in the last millimetre of the posterior end. • The tail is not spirally coiled. The cuticle is without transverse striation, but is finely striated

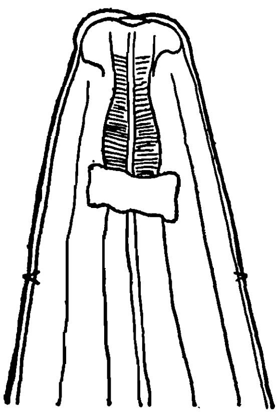

FIG. 10.—*Acanthocheilonema evansi.* Anterior end of female; dorsal view. (From Major Stewart's drawing.)

in the longitudinal direction. The head is truncate, and surrounded by a slight ridge which is more prominent laterally. This ridge is supported by five papillae on either side. Of these one is lateral, two sublateral and two submedian. The papillae are only very slightly prominent. There is no buccal capsule. The oesophagus is divided into two sections, a short anterior section in front of the nerve-ring, 0·204 mm. long, and a long posterior section of 6·506 mm. The anterior section is club-shaped, the posterior slightly sinuous. The nervering is broad and distinct. A pair of fine cervical papillae is present at 0·25 mm. from the anterior end. The tail measures 0·238 mm. in length. According to Major Stewart's notes, its "terminal portion is slightly enlarged, and bears three faint grooves on the posterior border." The vulva, which has a circular aperture, is situated at 0·595 mm. from the anterior end. The vagina is long, narrow, muscular, and folded transversely and longitudinally. The branches of the uterus originate at about 3·9 mm. from the head. They are distended with a mass of closely-packed embryos.

The tail of the male is spirally coiled and without alae. There are four pairs of preanal and three pairs of postanal papillae (fig. 11). The spicules are very unequal and dissimilar. The left is 1 mm. in length and is divided into a proximal, thicker, handle-like portion and a thinner, blade-like distal portion with the tip bent almost at a right angle. The right spicule is much shorter (0·179 mm.), thick, darker brown in colour and with a rough ventral surface..

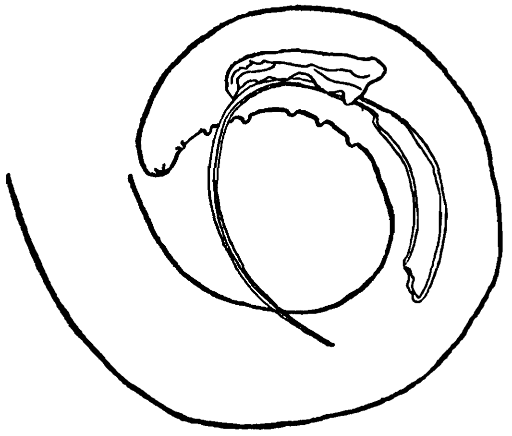

FIG. 11.—*Acanthocheilonema evansi.* Caudal end of male; lateral view. (From Major Stewart's drawing.)

The foregoing description is taken, with some modification, from Major Stewart's manuscript. We have placed this species in the genus *Acanthocheilonema* on account of the characters of the oesophagus, the spicules and the caudal papillae of the male. The members of this genus are usually referred to as having two pairs of postanal papillae in the male. We have examined specimens of *A. gracile*, and find that they have three pairs, and a pair of small cuticular appendages anterior to the most posterior pair of papillae. In *A. evansi* again there are three pairs of postanal papillae, and a small, flattened, terminal button. We have been unable to detect any lateral appendages. Possibly the "grooves" mentioned above in the female may indicate the existence of a rudiment of these structures.

Genus **Setaria** Viborg, 1795.

Setaria equina (Abildg., 1789).

A single female specimen from a horse.

Setaria sp.

Fragments, species unrecognizable, from the eye of a horse.

Subfamily ONCHOCERCINAE Leiper, 1911.

Genus **Onchocerca** Dies., in Herm., 1841.

Onchocerca sp.

From the subcutaneous tissue of a camel. Probably referable to *O. fasciata* Raill. and Henry, 1910.

Superfamily SPIRUROIDEA Raill. and Henry, 1915.

Family *SPIRURIDAE* Örley, 1885.

Subfamily SPIRURINAE Raill., 1915.

Genus **Habronema** Dies., 1861.

Habronema muscae (Carter, 1861).

One male and several females from a horse, from Egypt. A careful description of this species has been given by Ransom (1913).

Habronema megastoma (Rud., 1919).

(Figs. 12-16.)

Host: horse. Localities: Lahore, Punjab; Muktesar.

The literature on this species is very scattered and it seems desirable to give a short re-description of it, based in part on Major Stewart's notes.

The male measures about 8 mm. in length and up to 0·27 mm. in maximum thickness; the female about 11 mm. and up to 0·374 mm. respectively.

The head, which measures about 0·11 mm. in diameter, is separated from the body by a very distinct groove, a feature which serves to distinguish this species readily from *H. muscae* and *H. microstoma*. There is a "shoulder" of somewhat thickened cuticle immediately behind the groove. The mouth has four lips, two median (dorsal and ventral) and two lateral. The free edges of the dorsal and ventral lips are membranous, projecting slightly over the mouth-aperture. Each median lip has two submedian papillae, and each lateral lip one large papilla. Each of the submedian papillae has two terminations, the outer of which is situated on

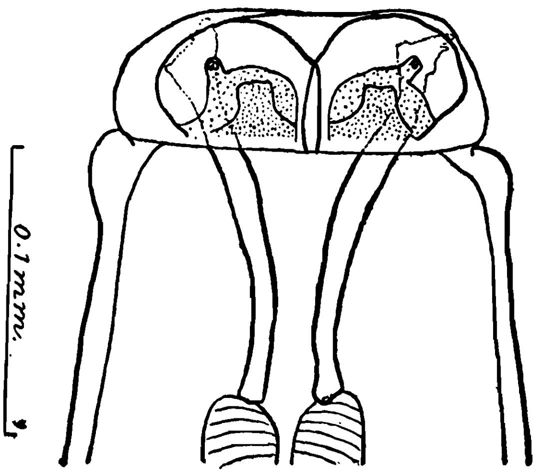

FIG. 12.—*Habronema megastoma.* Head of female; dorsal view. (Original.)

the external surface of the lip. The inner is supplied by a branch of the pulp which extends to the internal surface of the lip, and in a frontal view (fig. 14) is overlapped by the lateral lip. These inner terminations may function as the pores of the head-glands rather than as sensory organs.

The buccal capsule is funnel-shaped and measures about 0·13 mm. in length. Its wall, which is formed of two separate lateral halves, reaches to the edge of the mouth. The narrow anterior portion of the œsophagus is 0·185 mm. long, the thicker posterior portion about 0·89 mm. The nerve-ring is just anterior to the junction of the two portions.

The tail of the male is curled into a close spiral and is alate. It is flattened and expanded to form a lanceolate adhesive surface covered with rugae, which extend also on to the alae. There are four pairs of pedunculate preanal and five pairs of postanal papillae. Of the latter the four posterior pairs are ventrally situated, close to the median line, the three posterior pairs forming a symmetrical group close to the tip of the tail. The fifth postanal pair is situated just behind the cloacal aperture. The members of this pair are asymmetrical and more laterally placed. That of the right side is broad and stretches almost to the middle line, while that of the left side is much smaller. The spicules are very unequal. The left is 0·46 mm. long, cylindrical and strongly curved; the right shorter (0·24 mm.), flattened and grooved ventrally to receive the left spicule. There is a small accessory piece.

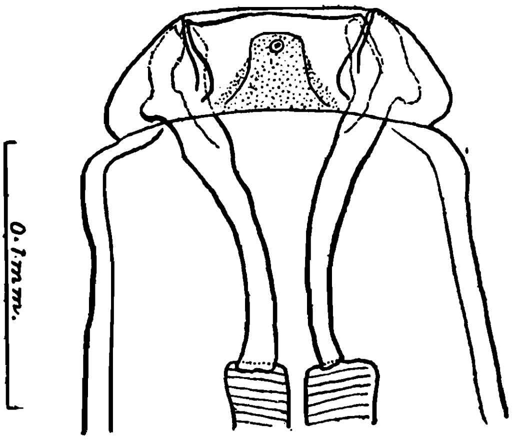

Fig. 13.—*Habronema megastoma*. Head of female; lateral view. (Original.)

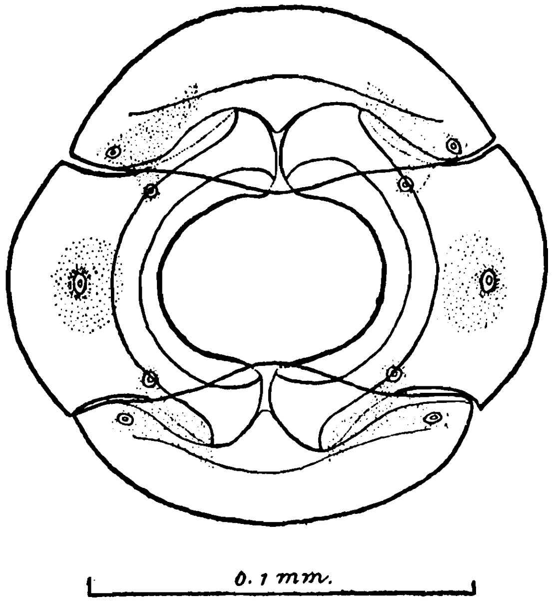

Fig. 14.—*Habronema megastoma*. Head of female; viewed *en face*. (Original.)

The tail of the female is 0·28 mm. long and bluntly conical. The vulva is situated at about the junction of the anterior and middle thirds of the body. Its orifice is surrounded by a small, raised, cuticular ring. It opens into a small muscular pouch, or "ovejector," directed dorsally and posteriorly from the vulva at an angle of about 45 degrees to the main axis of the body, and followed by a tube with thick, muscular walls (the structure frequently referred to by Seurat as a "vestibule"). There is no clear distinction between the vagina and the unpaired portion of the uterus. The muscular tube runs directly backwards from the pouch, its point of origin being on the posterior side of that organ. It measures about 0·8 mm. in length. The uterine branches are muscular near their origin. One runs straight backwards, the other doubles forwards after running posteriorly for some considerable distance. The uterus is packed with eggs containing fully-formed embryos.

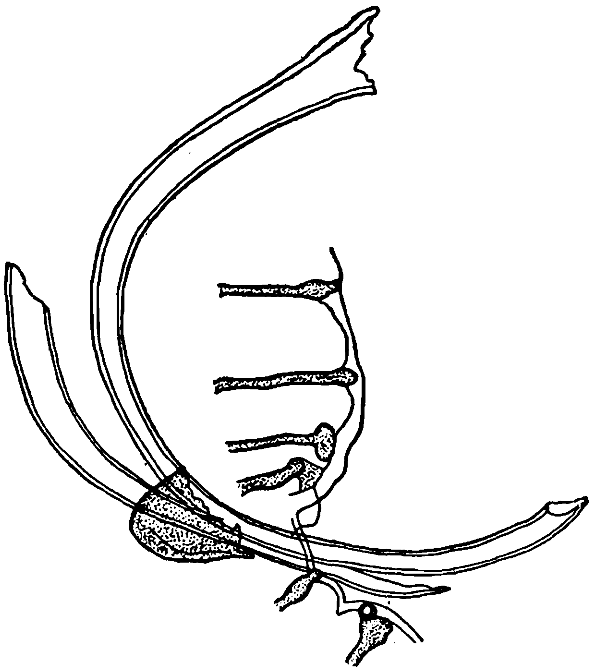

FIG. 15.—*Habronema megastoma.* Cloacal region of male (× 340); lateral view showing spicules, accessory piece and some of the papillæ. (From Major Stewart's drawing.)

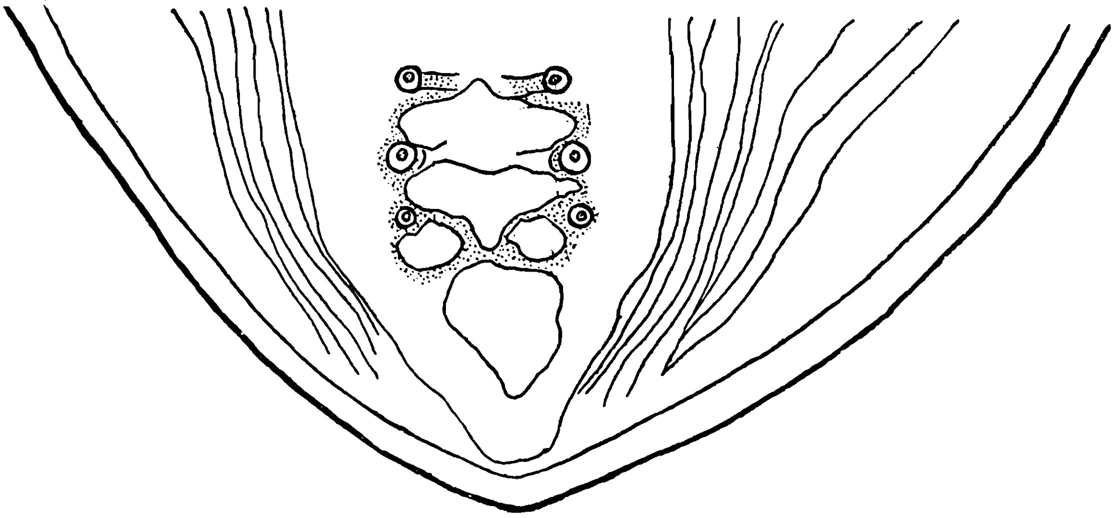

FIG. 16.—*Habronema megastoma.* Extremity of tail of male; ventral view. (From Major Stewart's drawing.)

Subfamily ARDUENNINAE Raill. and Henry, 1911.

Genus **Spirocerca** Raill. and Henry, 1911.

Spirocerca sanguinolenta (Rud., 1819).

This species has recently been redescribed and figured by one of us (Baylis, 1923*b*), and its affinities discussed. It is represented in the present collection by a few specimens from a dog. Locality, Lahore, Punjab.

Subfamily GONGYLONEMINAE Hall, 1916.

Genus **Gongylonema** Molin, 1857.

Gongylonema scutatum (Leuck., 1873).

This species occurs in the collection from the following hosts : Ox ; buffalo (*Bos bubalus*) ; " Kar kar[1] sheep."

Subfamily PHYSALOPTERINAE Stoss., 1898 (*fide* Stiles & Hassall).

Genus **Physaloptera** Rud., 1819.

Physaloptera praeputialis v. Linst., 1889.

Two females from the intestine of a domestic cat ; Museum compound, Calcutta.

Physaloptera quadrovaria Leiper, 1908.

A few specimens, in poor condition, already determined as *P. quadrovaria*, from the "stomach and body-cavity" of *Varanus exanthematicus*. Locality, Katagum, Northern Nigeria. (Presented to the Indian Museum by Dr. J. H. Ashworth.)

According to Seurat, *P. quadrovaria* is a synonym of *P. varani* Parona, 1899. Ortlepp (1923), however, who has re-examined the type-material of *P. quadrovaria*, states that *P. varani* " differs from *P. quadrovaria* by its longer œsophagus, shorter tail of the female, less evolved type of origin of the uteri, and also by the absence of denticles on the inner surface of the lips." In the present material the rows of small denticles on the lips, figured by Ortlepp for *P. quadrovaria*, are present, and in most other respects the specimens seem to agree better with this author's account of that species than with that of *P. varani*. The structure of the vagina and its connections, however, and the mode of origin of the uterine branches, conform more closely with his description of *P. varani*. Probably there is considerable variation in the arrangement of the female apparatus, as there is, for example, in that of *Tanqua tiara* (see Baylis and Lane, 1920, pp. 262-264). It seems unwise to attach very great importance to the precise mode of branching of the uterus (as apart from the number of branches) as a specific character. Characters based upon the armature of the lips, however, are probably much more stable, and for this reason we have adhered to the previous determination as *P. quadrovaria*.

Family *CAMALLANIDAE* Raill. and Henry, 1915.

Genus **Camallanides** Baylis and Daubney, 1922.

Camallanides prashadi Baylis and Daubney, 1922.

A few specimens from a rat-snake (*Zamenis mucosus*), collected in the Calcutta Zoological Gardens by Major Knowles, appear to belong to

---

[1] Almost certainly the urial (*Ovis vignei*).—*N. A.*

the same species as the material described in our former paper from *Bungarus fasciatus.*

Family *GNATHOSTOMIDAE* Raill., 1915, *emend.* Baylis and Lane, 1920.

Subfamily GNATHOSTOMINAE Baylis and Lane, 1920.

Genus **Tanqua** R. Blanchard, 1904.

Tanqua tiara (v. Linst., 1879.)

Material of this species occurs in the collection from —

(*a*) *Varanus salvator;* Zoological Garden, Calcutta.
(*b*) *Varanus nebulosus* (intestine); Ballygunj, Calcutta.
(*c*) *Varanus niloticus* and *V exanthematicus* (stomach); Northern Nigeria. (Dr. J. H. Ashworth.)

Tanqua anomala (v. Linst., 1904).

This species is represented by specimens preserved *in situ* in the stomach of a sea snake (*Hypsirhina enhydris*), collected by Col. F. Wall, I.M.S.

Family *THELAZIIDAE* Raill., 1916.

Genus **Thelazia** Bosc, 1819.

Thelazia rhodesii (Desm., 1828).

Two females, from the lacrymal canal of a bullock. This species has been dealt with by Railliet and Henry (1910).

Superfamily TRICHINELLOIDEA Hall, 1916.

Family *TRICHINELLIDAE* Stiles and Crane, 1910.

Subfamily TRICHURINAE Ransom, 1911.

Genus **Trichuris** Roederer, 1761.

Trichuris trichiura Roederer, 1761.

This species is represented in the collection by specimens from man.

Trichuris ovis (Abildg., 1795).

Examples from a sheep, collected at Lahore, Punjab.

Superfamily DIOCTOPHYMOIDEA Raill., 1910 (*fide* Travassos).

Family *DIOCTOPHYMIDAE* Raill., 1915.

Genus **Eustrongylides** Jägerskiöld, 1909.

Eustrongylides sp. (?)

Specimens found encapsuled in a fish (*Nemachilus yarkandensis*), from Yarkand. According to the label " there were more than six of these parasites, some more than 2 in. long. Of each one end was in coils inside a cyst, and the other end buried either in the body-wall, liver, testis or coils of the intestine." The worms are immature. Two specimens removed from their capsules measured 30·85 mm. and 28·45 mm. in length respectively. The œsophagus of the longer specimen was 9·75 mm. long, and that of the shorter 7·75 mm. The maximum thickness of each specimen was about 0·5 mm.

Superfamily STRONGYLOIDEA Weinland, 1858.

Family *STRONGYLIDAE* Baird, 1853, *s. s.* Lane, 1917.

Subfamily STRONGYLINAE, Raill., 1893, *s. s.* Leiper, 1908.

Genus **Strongylus** Müller, 1780.

Strongylus equinus Müller, 1780.

Examples from a horse. Locality, Egypt.

Strongylus vulgaris (Looss, 1900).

Three females from a horse. Locality, Egypt.

Strongylus edentatus (Looss, 1900).

Examples from a horse. Locality, Lahore, Punjab.

Genus **Cylicostomum** Raill., 1901.

Cylicostomum tetracanthum (Mehl., 1831) and *C. nassatum* (Looss, 1900) are represented by specimens from the horse.

Genus **Oesophagostomum** Molin, 1861.

Oesophagostomum (Proteracrum) radiatum (Rud., 1803).

A single female, from a buffalo (*Bos bubalus*).

Oesophagostomum (Proteracrum) columbianum Curtice, 1890.

A single female, from a sheep.

Genus **Kiluluma** Skrjabin, 1916.

Kiluluma stylosa (v. Linst., 1907).

Examples from the stomach of a rhinoceros (*Rhinoceros indicus*). Locality, Janakpore, Nepal.

Skrjabin (1916) has given a full account of this interesting species.

Subfamily DELETROCEPHALINAE Raill., 1916.

Genus **Diaphanocephalus** Dies., 1851.

Diaphanocephalus willeyi (v. Linst., 1904).

Specimens occur in the collection from the banded krait (*Bungarus fasciatus*). The species was redescribed in our earlier report (Baylis and Daubney, 1922).

Subfamily STEPHANURINAE Raill., Henry and Bauche, 1919 (*fide* Travassos, 1920 [?]).

Genus **Stephanurus** Dies., 1839.

Stephanurus dentatus Dies., 1839.

A few specimens, in very poor condition, from the portal vein of a pig. One of us (Daubney, 1923) has recently dealt with the anatomy and systematic position of this species.

Family *ANCYLOSTOMIDAE* Looss, 1911, *emend.* Lane, 1917.

Subfamily ANCYLOSTOMINAE Looss, 1905, *emend.* Lane, 1917

Genus **Ancylostoma** (Dubini, 1843) Creplin, 1845.

Ancylostoma duodenale (Dubini, 1843).

The collection contains examples of this species from man (India and Egypt), and also a single female from a tiger (Zoological Garden, Calcutta).

Ancylostoma caninum (Ercolani, 1859).

This species is represented by material from dogs (localities, Lahore, Punjab, and Kowloon, China), and from a wild jackal taken in the Museum compound, Calcutta.

Ancylostoma braziliense de Faria, 1910.

Syn. *A. ceylanicum* (Looss, 1911).

A few specimens from a dog. Locality, Kowloon, China.

Lane (1922) has recently supported the view, previously expressed by Leiper, that *A. ceylanicum* is merely a synonym of *A. braziliense*, by a careful comparison of Brazilian and Indian material. The same conclusion had also been reached by Gordon (1922).

Subfamily NECATORINAE Lane, 1917

Genus **Necator** Stiles, 1903.

Necator americanus (Stiles, 1902).

In our former report we referred to some examples of this species collected from an African rhinoceros (*Rhinoceros bicornis*) in the Zoological Garden, Calcutta. The present collection contains a single female specimen taken, along with *Crossocephalus brevicaudatus* and *Kiluluma stylosa*, from a wild Indian rhinoceros (*R. indicus*). This appears to afford good evidence that *N. americanus* occurs naturally in rhinoceroses. It does not seem at all likely that in the present case there has been any admixture of material from a different host, since among all the material received by us from the Zoological Survey we have found no specimens of *Necator* except those from rhinoceroses.

Genus **Tetragomphius** Baylis and Daubney, 1923.

The interesting species already briefly described (Baylis and Daubney, 1923, p. 334) under the name of *Tetragomphius procyonis* has affinities with both the subfamilies Ancylostominae and Necatorinae. In this respect it occupies a position somewhat similar to that of *Uncinaria* (see Baylis and Daubney, 1922, p. 337). We have considered it necessary to form a new genus, which may be defined as follows :—

Ancylostomidae : closely resembling *Uncinaria* in general appearance. Body somewhat tapered anteriorly, head bent dorsally. Mouth-capsule cup-shaped. No teeth at anterior margin. At base of capsule a pair of subdorsal and a pair of subventral teeth. General form of male genital bursa much as in *Uncinaria*. Tips of dorsal ray bifurcate. Spicules long, filiform and unbarbed. Vulva in posterior half of body.

Tetragomphius procyonis Baylis and Daubney, 1923.

(Figs. 17—20.)

Baylis and Daubney (1923), p. 334.

Host: raccoon (*Procyon* sp.). Locality, Zoological Garden, Calcutta.

The material consists of a large number of specimens taken from what appears, from histological examination, to be the pyloric end of the stomach. Most of the worms appear to have been inhabiting galleries in the substance of a fibrous tumour of the stomach-wall. The general appearance of the tumour is much like that of the tumours of the horse's stomach in which *Habronema megastoma* is found.

The males of the species measure from 13 to 15 mm. in length and up to 0·46 mm. in thickness ; the females from 16 to 20 mm. and up to 0·65 mm. respectively. There is a rather long, slender neck. The head, which is bent dorsally, is small in comparison with the general thickness of the body. It measures about 0·14 mm. in diameter. The cup-shaped buccal capsule is furnished at its base with a pair of subdorsal and a pair of subventral teeth. The subdorsal teeth are bicuspid, the stout conical cusps measuring from 11 to 18 μ in height. The subventral teeth are more slender structures, about 43 μ in height. They may appear bidentate or tridentate. The dorsal gutter is seen as a blunt tubercle in the dorsal wall at the base of the capsule. The œsophagus is about 0·65 mm. in length and up to 0·13 mm. in maximum thickness. The cervical papillae are at 0·6—0·7 mm. from the anterior end. They have the form of stout, well-developed, backwardly-projecting spines.

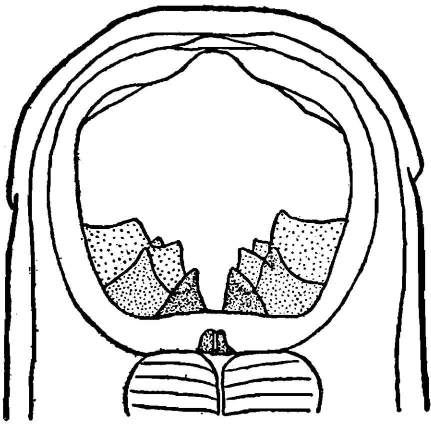

FIG. 17.—*Tetragomphius procyonis.* Head of female ; dorsal view. (Original.)

The genital bursa of the male is rather short and has a stunted appearance. In lateral view it cannot be distinguished from the bursa of *Uncinaria ;* that is to say, the ventral rays are slender and closely applied to each other, and the externo-lateral diverges somewhat from the other two lateral rays. The main trunk of the dorsal ray is short and exceedingly thick. Its two divisions are bifurcate at their tips. The genital cone is short and fairly stout. The spicules are filiform and extremely long. They measure from 7 to 8 mm. in length, and are drawn out into long, fine points posteriorly.

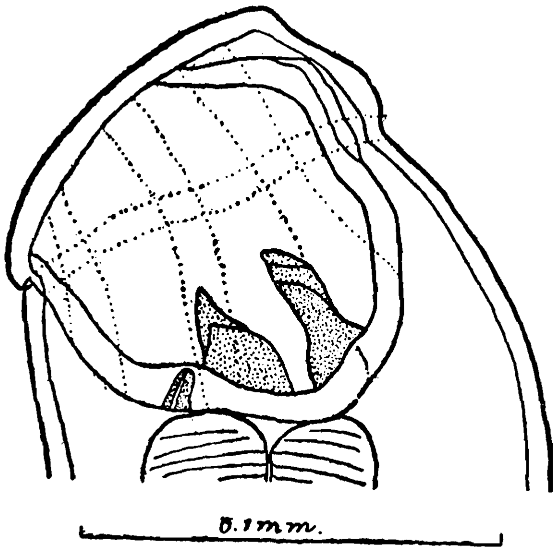

Fig. 18.—*Tetragomphius procyonis.* Head of female ; lateral view. (Original.)

The tail of the female is about 0·34 mm. long and bluntly pointed. The vulva is situated at from 3·6 to 4 mm. from the posterior extremity. Its opening is a transverse slit bounded by fairly prominent lips. There is a short transverse vagina and feebly-muscular ovejectors which run in opposite directions. After a short course backwards the posterior ovejector returns, running forwards past the vulva. Both branches of the uterus are anterior. The eggs in the vagina measure 0·076—0·082 mm. × 0·045—0·05mm., and are segmenting when deposited.

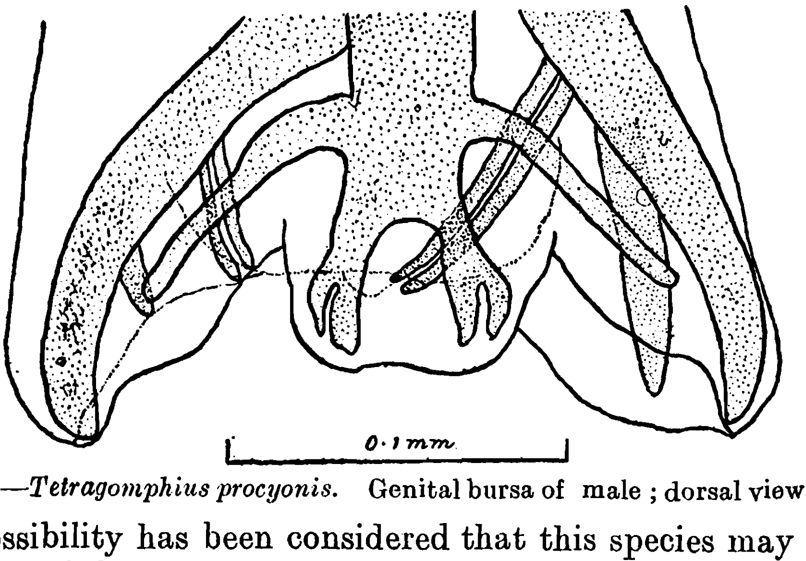

Fig. 19.—*Tetragomphius procyonis.* Genital bursa of male ; dorsal view. (Original.)

The possibility has been considered that this species may be identical with one of the two species described by Molin (1861) from *Procyon cancrivorus*. According to Molin, however, neither *Dochmius bidens* nor *D. maxillaris* exceeded 8 mm. in length in the case of the female.

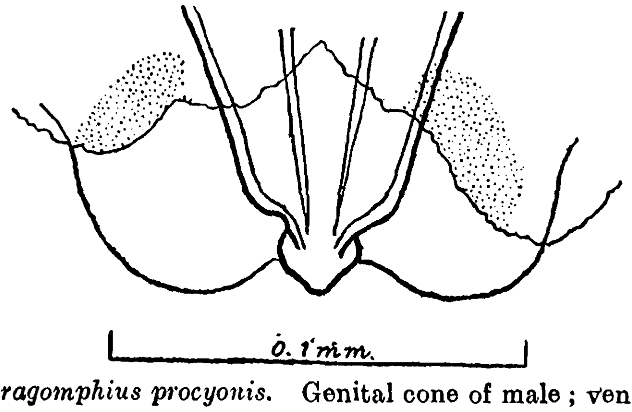

Fig. 20.—*Tetragomphius procyonis.* Genital cone of male ; ventral view. (Original.)

In the absence of figures of these two species, and having regard to the brevity of the descriptions, we have considered the measurements sufficient to warrant our leaving these species out of consideration.

Family *THICHOSTRONGYLIDAE* Leiper, 1912.

Subfamily Trichostrongylinae Leiper, 1908.

Genus **Haemonchus** Cobb, 1898.

Haemonchus contortus (Rud., 1803).

A few specimens from a sheep.

Haemonchus longistipes Raill. and Henry, 1909.

From a camel.

This species has recently been carefully redescribed by Boulenger (1921).

Genus **Nematodirus** Ransom, 1907.

Nematodirus sp.

Fragmentary material from a camel. It is impossible to determine the species.

Genus **Mecistocirrus** (Raill. and Henry, 1912) Neveu-Lemaire, 1914.

Mecistocirrus fordii (Daniels, 1908).

A few female specimens from the abomasum of a calf.

Genus **Oswaldocruzia** Travassos, 1917.

Oswaldocruzia filiformis (Goeze, 1782).

Two females from *Bufo melanostictus* ; locality, Nankouri Island, Nicobars. Collected by Major R. B. S. Sewell, I.M.S.

Family *METASTRONGYLIDAE* Leiper, 1908.

Subfamily Metastrongylinae Leiper, 1908.

Genus **Metastrongylus** Molin, 1861.

Metastrongylus apri (Gmel., 1790).

Fragmentary material from the bronchi of a pig.

Genus **Dictyocaulus** Raill. and Henry, 1907.

Dictyocaulus filaria (Rud., 1809).

Examples from the lungs of a sheep.

Subfamily RICTULARIINAE Hall, 1913.

Genus **Rictularia** Fröl., 1802.

Rictularia cahirensis Jägerskiöld, 1904.

Several female specimens, apparently of this species, were taken from the intestine of a civet (*Viverricula malaccensis*).

R. cahirensis was originally described from the domestic cat in Cairo, and has also been recorded by Vevers (1923) from the South American Azara's fox (*Canis azarae*).

[Superfamily ?]

Family *MERMITHIDAE* Braun, 1883.

Genus **Mermis** Duj., 1842.

Mermis nigrescens Duj., 1842.

A single mature female, which we refer to this common European species, was taken at Pashok, Darjiling district, Eastern Himalayas, at an altitude of 4,000 feet. The ova of this specimen are of the same form and size as those of European specimens of *M. nigrescens*, but the inner shell does not show the usual rather dark brown colour, being almost colourless. This may perhaps be only a matter of age.

Genus **Mermis,** *sens. lat.*

In the introduction to our earlier report it was stated that the first collection included some Mermithidae. It was hoped that a study of these might lead to results worthy of publication at a later date. Unfortunately, however, these worms have all proved to be immature, and we have not felt justified in reporting upon them in detail.

REFERENCES.

BAIRD, W 1859.—Description of a Rare Entozoon from the Stomach of the Dugong. *Proc. Zool. Soc. Lond.*, pp. 148-149, pl. lvi.

BAYLIS, H. A. 1919.—A new species of the Nematode Genus *Crossocephalus* from the Rhinoceros. *Ann. Mag. Nat. Hist.* (9) IV, pp. 94-98.

BAYLIS, H. A. 1920.—On the Classification of the Ascaridae. I.—The Systematic Value of certain Characters of the Alimentary Canal. *Parasitol.* XII, 3, pp. 253-264.

BAYLIS, H. A. 1921.—On the Classification of the Ascaridae. II.—The *Polydelphis* group, etc. *Parasitol.* XII, 4, pp. 411-426.

BAYLIS, H. A. 1923*a*.—Report on a Collection of Parasitic Nematodes, mainly from Egypt. Part I.—Ascaridae and Heterakidae. *Parasitol.* XV, 1, pp. 1-13.

BAYLIS, H. A. 1923*b*.—On the Nematode Genus *Streptopharagus*, with some Remarks on the Genus *Spirocerca*. *Trans. Roy. Soc. Trop. Med.* and *Hyg.* XVI, 8, pp. 486-497.

BAYLIS, H. A., AND DAUBNEY, R. 1922.—Report on the Parasitic Nematodes in the Collection of the Zoological Survey of India. *Mem. Ind. Mus.* VII, 4, pp. 263-347.

BAYLIS, H. A., AND DAUBNEY, R. 1923.—Preliminary Descriptions of three new parasitic Nematodes. *Ann. Mag. Nat. Hist.* (9) XI, pp. 333-335.

BAYLIS, H. A., AND LANE, C. 1920.—A Revision of the Nematode Family Gnathostomidae. *Proc. Zool. Soc. Lond.*, pp. 245-310, pls. i-viii.

BOULENGER, C. L. 1921.—On some Nematode Parasites of the Camel in India. *Parasitol.* XIII, 4, pp. 311-314.

BOULENGER, C. L. 1922.—On *Ascaris vitulorum* Goeze. *Parasitol.* XIV, 1, pp. 87-92.

DAUBNEY, R. 1923.—The kidney-worm of Swine: a short Redescription of *Stephanurus dentatus* Diesing, 1839. *Journ. Comp. Pathol. & Therap.* XXXVI, 2, pp. 97-103.

DUJARDIN, F. 1845.—*Histoire naturelle des Helminthes.* Paris.

GEDOELST, L. 1916.—Notes sur la Faune parasitaire du Congo belge. *Rev. Zool. Africaine* V, Fasc. 1.

GORDON, R. M. 1922.—Ancylostomes recorded from 67 post-mortems performed in Amazonas. *Ann. Trop. Med. & Parasitol.* XVI, 2, pp. 223-228.

JÄGERSKIÖLD, L. A. 1893.—*Bidrag til Kännedomen on Nematoderna.* Akademisk Afhandling, Stockholm. 86 pp., 5 pls.

JÄGERSKIÖLD, L. A. 1894.—Beiträge zur Kenntniss der Nematoden. *Zool. Jahrb.*, Anat., VII, pp. 449-532, pls. xxiv-xxviii. (A German version of 1893.)

KRABBE, H. 1878.—Saelernes og Tandhvalernes spolorme. *K. Dansk. Vidensk. Selsk. Forh.*, pp. 43-51, pl. i.

LANE, C. 1922.—*Ancylostoma braziliense. Ann. Trop. Med. & Parasitol.* XVI, 4, pp. 347-352.

LINSTOW, O. VON. 1899.—Nematoden aus der Berliner Zoologischen Sammlung. *Mitt. Zool. Mus. Berlin* I, 2, pp. 1-28, pls. i-vi.

LINSTOW, O. VON. 1904.—Nematoda in the Collection of the Colombo Museum. *Spolia Zeylanica* I, 4, pp. 91-104, pls. i-ii.

LINSTOW, O. VON. 1906*a*.—*Ascaris halicoris* Baird. *Journ. & Proc. Asiat. Soc. Bengal* I, 10, pp. 258-260, pl. xi.

LINSTOW, O. VON. 1906*b*.—Neue und bekannte Helminthen. *Zool. Jahrb.*, Syst. XXIV, pp. 1-20, pl. i.

LINSTOW, O. VON. 1907.—*Ascaris lobulata*, Schneider, ein Parasit des Darms von *Platanista gangetica*. *Journ. & Proc. Asiat. Soc. Bengal* III, pp. 37-38.

MACFIE, J. W. S. 1922.—The *Ascaris* of Cattle. *Ann. Trop. Med. & Parasitol.* XVI, 3, pp. 311-313.

MOLIN, R. 1861.—Il Sottordine degli Acrofalli, etc. *Mem. R. Ist. Veneto* IX, pp. 427-633, pls. xxv-xxxiii.

ORTLEPP, R. J. 1923.—The Nematode Genus *Physaloptera* Rud. *Proc. Zool. Soc. Lond.* pp. 999-1107

PARONA, C. 1889.—Intorno all' *Ascaris halicoris*, Owen, ed a qualche altro Nematode raccolti in Assab dal Dott. V Ragazzi. *Ann. Mus. Civ. Stor. Nat. Genova* (2) VII. (XXVII), pp. 751-764, pl. xiii.

RAILLIET, A., AND HENRY, A. 1910.—Les Thélazies, Nématodes parasites de l'oeil. *Compt. Rend. Soc. Biol.*, Paris, LXVIII, pp. 213-216.

RANSOM, B. H. 1913.—The Life History of *Habronema muscae* (Carter), a Parasite of the Horse transmitted by the House Fly. *U. S. Bur. Anim. Indust. Bull.* 163. 36 pp.

SCHNEIDER, A. 1866.—*Monographie der Nematoden.* Berlin.

SKRJABIN, K. I. 1916.—Parasitic Trematodes and Nematodes, etc. *Scientific Results of the Zool. Exp. to Brit. E. Africa and Uganda made by Prof. V Dogiel and I. Sokolow in the year 1914.* Petrograd. Vol. I, No. 4. Russian, pp. 1-98. English translation, pp. 99-157. Pls. i-x.

SMITH, A. J., FOX, H., AND WHITE, C. Y. 1908.—Contributions to Systematic Helminthology. *Univ. of Pennsylv. Med. Bull.*, Philadelphia, XX, 12, pp. 283-294, pls. i-x (preceding text).

STEWART, F. H. 1914.—Studies in Indian Helminthology, No. I. *Rec. Ind. Mus.* X, pp. 165-193, pls. xviii-xxiii.

STILES, C. W., AND HASSALL, A. 1899.—Internal Parasites of the Fur Seal. (In " The Fur Seals and Fur Seal Islands of the North Pacific Ocean.") *Report on Fur Seal Investigations*, Washington. Part 3, pp. 99-177.

VEVERS, G. M. 1923.—On the Parasitic Nematoda collected from Mammalian Hosts which died in the Gardens of the Zoological Society of London during the years 1919-1921, etc. *Proc. Zool. Soc. Lond.* pp. 901-919.

YORKE, W., AND SOUTHWELL, T. 1920.—*Crossocephalus zebrae*, n. sp. *Ann. Trop. Med. & Parasitol.* XIV, 1, pp. 127-135.

OBSERVATIONS ON THE FAUNA OF CERTAIN TORRENTIAL STREAMS IN THE KHASI HILLS.

By SUNDER LAL HORA, D.Sc., *Assistant Superintendent, Zoological Survey of India.*

The following notes are based on the results of two visits paid to the Khasi Hills, in November, 1921 and February, 1923, in order to study the habits and mode of life of fish and tadpoles of certain torrential streams in the neighbourhood of Cherrapunji. Some of the observations taken on the first occasion have already been published,[1] while more extensive and detailed experiments recently carried out are incorporated in this paper. The paper has been divided into several sections, each of which deals with some particular type of observations. In the general account I have endeavoured to describe the main factors which influence the fauna of the Khasi Hills, and to give a short account of the aquatic animals collected during the two visits.

I am greatly indebted to Dr. N. Annandale for numerous valuable suggestions and for the identification of tadpoles and molluscs and to Dr. S. W. Kemp for naming aquatic crustacea. To Prof. C. V Raman, Palit Professor of Physics in the Calcutta University, I am highly obliged for co-operation and valuable suggestions in working out the mechanism of the diverse types of adhesive apparatus found in the fish and tadpoles of mountain torrents.

CONTENTS.

GENERAL ACCOUNT OF THE COUNTRY AND THE FAUNA.

To a student of the fauna of rapid waters, the streams in the Khasi Hills have a special significance and particularly those that flow in the neighbourhood of Cherrapunji. The plateau of Cherra is known all the world over for its heavy rainfall, the annual average of which is no less than 458 inches. The greater portion of this falls in a comparatively short time, *i.e.*, between the months of May and August. " In 1861, 905 inches fell, 366 of which were assigned to July alone. The maximum for a single day was, however, recorded in 1876, when 41 inches of rain fell in 24 hours."[2] Enormous though the rainfall is, the plateau is admirably drained and the water is quickly carried off. These two

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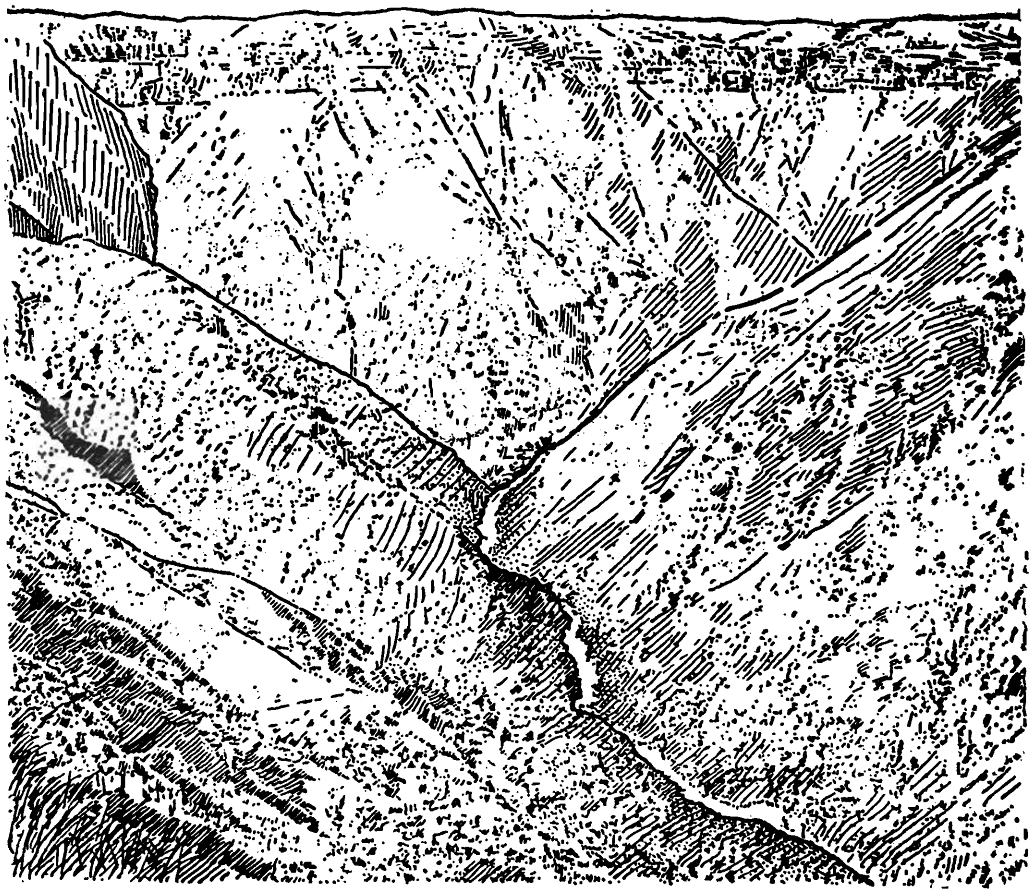
[1] Hora, *Rec. Ind. Mus.* XXV, pp. 4-8 (1923); *Journ. Asiat. Soc, Bengal* (n. s.) XVIII. pp. 9-15 (1921).

[2] Allen, *Assam District Gazetteers* X, p. 30 (1905).

factors (*i.e.*, the heavy rainfall and the quick drainage) cause the streams in this area to swell up greatly and often suddenly in the rainy season and impart to them the characteristic impetuosity of mountain torrents. During my two visits I had bright sunny days and was thus able to collect the fauna of the streams and make observations on them. As a collector of hill-stream fauna it did not suit me to visit these hills in the rainy season and thus I have not been able to observe the inundation of the streams. Mr. Oldham who visited these hills in that season observes that he " took an opportunity of visiting one of the streams in these hills after a heavy and sudden fall of rain. The water had then risen only about thirteen feet above the level at which it stood a few days previously ; the rush was tremendous—huge blocks of rock measuring some feet across, were rolled along with an awful crashing, almost as easily as pebbles in an ordinary stream. In one night a block of granite, which I calculated to weigh upwards of 350 tons, was moved for more than 100 yards ; while the torrent was actually turbid with pebbles of some inches in size, suspended almost like mud in the rushing stream."[1]



TEXT-FIG. 1.—Bird's-eye view of the Nong-priang stream from Cherra plateau. From a photograph.

As a direct consequence of the heavy rainfall and the tremendous rush of water the streams on the sourthern portion of the hills flow into curiously deep and narrow gorges. The Nong-priang stream, to the fauna of which special attention was paid, flows some 3,000 feet below

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[1] Oldham, *Mem. Geol. Surv. India* I, p. 174 (1859).

the level of Cherrapunji. In the accompanying figure is given a bird's-eye view of the glen excavated by this stream. "In outline, all these river gorges or glens are remarkably alike; the upper portion of their sides being nearly perpendicular and peculiar faces of rock, which rest upon a rapidly inclined talus, sloping down to the level of the water beneath."[1] The hills along the southern borders rise almost straight from the plain to a height of 4,000 feet and on a clear day the plains of Sylhet are distinctly visible from the Cherra plateau. It is this abrupt rise in level which stops the south-west monsoon and precipitates the moisture in the hills close by.

The stream beds are usually formed of big boulders and stones, but sometimes it so happens that for a considerable length the bed is formed by a single rock in which the rushing water has formed, with the aid of loose pebbles, pot-holes here and there. Such a bed is seen along the roadside a few yards below the village of Moasmai. The presence of pot-holes in the streams of the plateau is a common feature and these form convenient hiding places for small fish and prawns and breeding places for insects, especially for mosquitoes.

One of my objects in going to these hills was to study experimentally the quantity of gaseous matter dissolved in the water of the hill-streams and to compare it with that found in the sluggish waters of level country. In a former paper[2] dealing with the structural modifications in the fish of mountain torrents I assumed that the water of hill streams is better oxygenated than that of streams in the plains, and I have now found this to be true by collecting the air given out by a certain fixed quantity of water when heated to a definite temperature. An account of the apparatus used in determining the quantity of air dissolved in various waters and the data obtained from experiments are given in an appendix to this paper. These experiments show that the stream-water in the plateau of Cherrapunji contains three times more air dissolved in it than the water of the Brahmaputra at Gauhati and at least five times more than the water of the river Hugli at Calcutta. The amount of air dissolved in the waters of the streams depends upon several factors. Some of these are temperature, rapidity of flow, clearness and shallowness of the water, and lastly the nature of the bed on which it flows. In all these points the hill-streams are more favourably situated than the sluggish streams in level country.

Before proceeding with the discussion of the fauna it will be worth while to summarize here the conditions to which the aquatic animals are subjected in this district. The first and the foremost from the point of view of animal ecology is the heavy rainfall and consequently the sudden rush of water in the streams. It is chiefly owing to this factor that the fauna of these streams has undergone considerable modifications. The second factor is the rocky bottom and the presence of big boulders and of pot-holes in it. These naturally form hiding places for certain animals and aid them in tiding over unfavourable conditions such as floods, danger from enemies, etc. The absence of any vegetation in

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[1] Oldham, *loc. cit.*, p. 173 (1859).

[2] Hora, *Rec. Ind. Mus.* XXIV, p. 43 (1922).

the rushing streams, their clear and well-oxygenated water are some of the other factors.

I propose now to discuss briefly the aquatic fauna of the Cherra hills in a general way and for this I will take up the various groups one by one.

Three different types of tadpoles are found in the Nong-priang stream. (1) Tadpoles of *Rana alticola* are found in large pools where water is comparatively quiet or is not flowing rapidly. These tadpoles are not provided with any kind of adhesive apparatus for life in rapid waters.[1] (2) The second type is represented by the tadpoles of *Rana afghana.* This species possesses a well-developed rounded sucker behind the mouth which is very efficient and helps the animal in sticking to rocks in rapid waters. The tadpoles were usually found sticking to the sides of rocks in clear rapid waters and were observed to crawl by the muscular action of the anterior lip which was thrust forwards at regular intervals and pulled the animal forwards. During this movement it was observed that the central portion of the disc was raised and lowered thus making and breaking its suctorial action. In the flat form of the body and stream-line curve of its dorsal profile the animal shows marked specialization for life in rapid waters. (3) The tadpoles of *Megalophrys,* with a funnel-like structure round the mouth, represent the third type. A few of these tadpoles (*M. robusta*) were found to live under rocks and stones in still water at the edge of the Nong-priang stream, but others (*M. parva*) were found to be plentiful in small clusters of water-weeds growing in moderately rapid waters in the course of a small stream below the dâk bungalow at Dumpep. They were living in such a way among weeds that they could either be obtained in bag-nets when the weeds were uprooted, or by violently shaking masses of weed. My observations on the funnel-shaped apparatus of this tadpole are given in a separate section of this paper.

The fish-fauna of the streams on the plateau of Cherra is very poor. I was able to collect specimens of *Ophiocephalus gachua, Danio aequipinnatus* and *Barbus tor* (*s. l.*). The first is a mud-fish and lives in marshes or small crevices on the sides of streams. *Danio aequipinnatus* s a small fish which is abundantly found in pot-holes or deep pools in the course of streams. It probably tides over floods by taking shelter under rocks and its small size is a distinct advantage for this purpose. The species was found to be heavily parasitized in November, 1921 by a flatworm, which has been identified by Mr. T. Southwell[2] as *Ligula intestinalis.* Big fishes of the genus *Barbus,* such as *B. tor,* ascend the hill-streams by muscular effort for breeding purposes and are adapted for life in rapid waters by their slender form and powerful musculature.

Of the fishes that live in the Nong-priang stream, however, almost all are much more specially suited for life in mountain torrents. *Barbus tor* was also found there, but this fish, as is pointed out above, ascends hill streams in winter for breeding purposes only and most of the larger female specimens were found to be full of eggs in February. There is a small loach inhabiting this stream. Though this species is not provided with any adhesive apparatus for sticking to

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[1] Annandale and Hora, *Rec. Ind. Mus.* XXIV, p. 506 (1922).
[2] Southwell, *Ann. Trop. Med. Parasit.* XVI, p. 380 (1922).

stones, its small size and subcylindrical form are great assets in so far as they enable it to hide among stones. The readiness with which it seeks such shelter is extraordinary. The other fishes are those belonging to the highly modified genera *Garra*, *Balitora*, *Pseudecheneis* and *Glyptothorax*, all of which are provided with special apparatus with which to contend against the force of rushing water.

It will be worth while in this connection to mention the local names under which these highly specialized fishes are known at Cherrapunji. *Balitora brucei* is called *Emine-dam* or flat fish, *dam* refers to the flat under surface of the fish. *Emine-tari* is the name for *Pseudecheneis sulcatus ; tari* in Khasi language means moustaches and in the name of the fish it has reference to its barbels which are drawn out at either angle of the mouth as moustaches. *Glyptothorax striatus* is known as the black fish — *Emine-yong*. There are two species of *Garra* inhabiting these streams, *Garra gotyla* and *G. lissòrhynchus*. The members of this genus are known under several appropriate names. *Sherdong* refers to the habit of these fish, which stick to rocks in waterfalls and which swim round a fisherman when he goes out to catch them ; *dong* means circling round. Adults of *Garra gotyla* are called *Udoharkhmut ;* the name refers to the proboscides on the snout =" double-nosed fish." During floods these fish are said to climb up rocks in rapid waters in shoals and hence the Khasi name *Usher-keu*, for *keu* means to climb up. The tadpoles of *Rana afghana* are known as the " stone-suckers," *Eu-lun*.

Only two species of aquatic crustacea were obtained from the streams in the Khasi Hills, a prawn (*Paleamon hendersoni*) and a crab (*Paratelphusa* (*Barytelphusa*) *falicidigitis*). Both these animals live in small crevices among rocks in water and sometimes the crabs are dug out from burrows on the sides of the streams. There is a peculiar method by which the prawns are captured in the district. At a suitable place a piece of cloth is spread at the bottom of the stream in such a way that it is held by men on the shore and can be readily pulled out. A quantity of rice is chewed and spat on this cloth. Prawns come out after a short time to feed on this food and when a sufficient number of them has collected on the cloth, it is pulled out and the prawns are captured and transferred to a small basket. In this way a large number of these animals are captured in the plateau of Cherrapunji.

Only one species of aquatic mollusc was found in the streams at Cherra. It is identified as *Vivipara bengalensis*. The mollusc lives in marshy places or among weeds growing in the still portions of the streams. From the base of the Khasi hills at Therriaghat were obtained two other species of molluscs namely, *Paludomus stephanus* and *Acrostoma variabile*. The former is adapted for life in rapid waters and possesses a large foot and a strong musculature connected therewith. Its upper whorls are usually eroded and the shell assumes a more or less spherical form. In *Acrostoma* the upper whorls are also worn away, but in this animal the shell is strongly ribbed and the foot is fairly muscular. These shells are found among pebbles and superficially look like them.

A number of insect larvæ were collected in a small stream at Dumpep. May-fly larvae were found moving about on rocks in fairly rapid water and their forms were observed to be specially adapted for life in swift currents. Dragon-fly larvae were also numerous, but they were chiefly found among water-weeds. Some of the dragon-fly larvae were also seen crawling about on rocks.

In the following sections I propose to describe some particular observations in detail.

CERTAIN POINTS IN THE ANATOMY OF HILL-STREAM TADPOLES.

Of the three types of tadpoles found in the Nongpriang stream below Cherrapunji, each is suited to a particular type of environment and has consequently evolved certain adaptive structures which are quite different from those found in the others. The tadpole of ***Rana** alticola*, living as it does in slow-running water, has no special kind of peculiar structures to enable it to withstand floods. Its carnivorous habits, the large size and powerful tail are advantageous, while its conspicuous colouration is probably correlated with its paratoid glands, the profuse secretion of which must be regarded as a protection against its enemies. Support is lent to this suggestion by the fact that the tadpole makes no attempt to conceal itself by day light, but hides by night.

The tadpole of *Rana afghana* is solidly built and is provided with a definite sucker on its ventral aspect behind the mouth. This organ enables it to live in rapid water sticking to rocks and stones at the bottom. Dr. Annandale and I have already discussed in detail the structure and function of the sucker[1], but there are certain other points in the anatomy of this tadpole which are worth mentioning here. It is well known that almost all the tadpoles are capable of crawling by the help of their lips, but in the tadpoles of *R. afghana* and its allies the muscles controlling this movement are very powerful, since the tadpole, unlike most others, has to crawl on rocks in a swift current. I have observed that the animal first projects the portion of the head anterior to the mouth, and then the rest of the body is pulled forwards as in a leech. The sucker during this process is continually engaged and disengaged and an up and down movement of the central callous portion can be seen by placing the animal in a glass dish full of water.

The muscles of the body-wall behind the sucker are well developed. Anteriorly they are attached to the posterior border of the central callous portion of the disc and posteriorly to the vertebral column near the hind limbs. These muscles, in all probability, take part in the formation of the sucker. The chief point of interest in the internal anatomy of this tadpole is the nature of its lungs. In full-grown tadpoles they are very small and can only be made out after a careful dissection. Indeed, even in those specimens in which the hind limbs are in an advanced stage of development, they are still quite small and it seems probable that the organ grows with rapidity during the final period of metamorphosis. In the reduction of the lungs in this tadpole we have another instance of communal convergence between the fish and tadpoles of rapid streams. It has been shown in one of my former communications that the air-bladder in hill-stream fishes is greatly reduced and in

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[1] Annandale and Hora, *Rec. Ind. Mus.* XXIV, p. 508 (1922).

extreme cases is enclosed in small bony capsules. The reason for this is obvious, for in those forms which lead a ground life a pneumatic structure is distinctly harmful: what is needed under the circumstances is solidity and not bouyancy. The reduction of the lungs in the tadpoles is thus analogous to the reduction of the bladder in fishes. Further the lungs, it appears, are not capable of taking on a respiratory function so long as the tadpole continues to live in rapid waters, in the abundant oxygen of which respiration is probably rendered possible by means of the blood vessels in the tail, etc.

The lungs in the tadpoles of *Megalophrys*, on the other hand, are modified in such a way as to form distinct hydrostatic organs very much of the nature of the air-bladder in fishes. At an early stage they are represented by two thin-walled sacs which are usually distended with air and are perhaps analogous to the air-sacs of birds. The sacs are divided into several compartments of varying dimensions and each of these lodges a bubble of air. By dissecting a large number of tadpoles I have found that with the growth of the animal the walls of the air-sacs are thickened and their capacity and outward dimensions considerably decreased. The thickening of the walls of the sacs usually commences at the hinder end, but in some cases the condition was that of a true lung with a small, thin-walled rounded chamber at its hinder end. Thus one could trace all stages from the thin-walled sac to the formation of a definite lung. I have sketched some of these stages in the accompanying figure. The air-chambers are likely to be pricked during dissection and in this case bubbles of air can be seen coming out.

TEXT FIG. 2.— Diagrammatic representation of the four phases of the lung in the tadpoles of *Megalophrys parva* Blgr.

Broken line indicates boundary of thin-walled sac, while full line represents the portion of the same definitely transformed into a lung.

OBSERVATIONS ON THE ORAL APPARATUS OF THE TADPOLES OF THE GENUS *Megalophrys*.

The funnel-shaped oral apparatus of certain tadpoles of the genus *Megalophrys* has received considerable attention during recent years. Most of the references to the literature on the subject are given at the end of my paper[1] published in the *Journal of the Asiatic Society of Bengal* last year, but since then we have received a valuable contribution to our knowledge by Dr. H. Boschma[2]. The observations made by him to a great extent confirm those recorded previously by several authors

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[1] Hora, *Journ. As. Soc. Bengal* (n. s.) XVIII, pp. 9-15 (1922).

[2] Boschma, *Bijdr. Dierkunde Amsterdam*, (Max Weber Feest-nummer) XXII, pp. 9-12 (1922).

He observed with the help of carmine powder that during respiratory movements a definite current carrying microscopic food particles entered the funnel from its two angles and that some particles also flowed in towards the mouth from the side of the lower lip. The passage of the current was not obstructed by the horny projections, which are absent in the region of the mechanical folding of the funnel. During my recent visit to the Khasi Hills I tried similar experiments with carmine powder. My observations were made on the tadpoles of *Megalophrys parva.* I introduced a small quantity of carmine solution in the neighbourhood of a tadpole lying at the bottom with the funnel folded. The carmine particles were sucked into the mouth along with the inspiratory current from all sides and a red stream was immediately observed to flow out from the aperture of the branchial chamber. It was also observed that carmine was being vigorously discharged through the nostrils. Whenever any large particle was brought in with the current, it was immediately spouted out and thrown away to a considerable distance. The currents were not so easy to observe when the tadpole came to the surface and expanded its funnel, for in this position it remained only for a very short time and then sank to the bottom with the funnel folded. But under no circumstances was I able to observe such a definite horizontal current as is shown by Dr. Boschma in his figure. It does not appear to me likely that the animal in its natural habitat comes to the surface and expands its funnel for feeding purposes, for I believe that in nature, as under artificial conditions, the tadpole spends most of its time under water with the funnel folded. But then it may be asked why does the tadpole come to the surface at all? I now attempt to answer this question in the light of the observations made in the field and certain anatomical peculiarities revealed by the dissection of the animal in the laboratory.

It has already been pointed out by me that when the animal comes to the surface and expands its funnel, the surface immediately above the funnel projects slightly upwards. Moreover, it was suggested by Dr. Annandale that the horny projections on the funnel of *Megalophrys* tadpoles are probably used for breaking through the surface film when the tadpole rises up. Both these phenomena suggest that the tadpole comes to the surface to have an intimate contact with the atmospheric air. From the changes undergone by the lungs in this form in the course of larval development, it appears quite probable that the tadpole rises to the surface to take in or give out a certain quantity of air, which is stored in the lungs. I tried to drown a tadpole by keeping it under a wire gauze in water but after 5 or 6 hours of this treatment it remained quite lively. From this I conclude that the air taken in is not essential for respiration and that the lungs in the early stages of development act mainly as hydrostatic organs, just as the air-bladder of certain fishes does. I have often observed large bubbles of air being given out by these tadpoles, both under water and after coming to the surface.

In the region of the mechanical folding of the funnel I have not been able to find any cilia either in the living animal observed under a fairly high power of the microscope or in microtome sections of the funnel. If there is any such current as is shown in Boschma's figure, it is in all probability initiated and carried on by the respiratory movements of the mouth and is not guided in its course by ciliated cells.

There seems to me no doubt that the oral apparatus of the tadpole is capable of acting as a float both when the funnel is expanded and the tadpole hangs down from the surface film and when it is folded, in which case the tadpole takes up different positions under water. I found that when the funnel-shaped apparatus was cut off in a living tadpole its movements became of a different nature. The animal with the float removed could not come to the surface of the water and whenever it moved from place to place, its head was continually knocking against the bottom and the movements were not so fast as they would have been in the case of a normal tadpole. Whenever such a mutilated tadpole was dropped in water it sank to the bottom with its head pointing downwards, while in the normal tadpole, though it was dropped with the head downwards to start with, the head always turned upwards before sinking to the bottom. The bowl in which these experiments were carried out held water 6 to 7 inches deep.

So many functions have already been assigned to this lozenge-shaped apparatus that it is not without hesitation that I add another to their number. It has been observed by several naturalists that under water the funnel is always folded and presents the appearance of two horns turned upwards and inwards. I think that in this position the lateral portions of the funnel, which are curved in like hooks, in all probability enable the animal to anchor itself among weeds in fairly rapid currents. I have pointed out in a previous section how difficult it was to dislodge these tadpoles from weeds and it was only after the weeds were either uprooted or violently shaken with a bag-net that some specimens were obtained. It is this fact which suggested to me the above-mentioned function of the oral apparatus of the *Megalophrys* tadpoles. An apparatus of the nature of an anchor is certainly very useful to an animal inhabiting rapid streams.

Thus in all probability the funnel of certain *Megalophrys* tadpoles discharges several functions, though it may have originally been evolved for a definite purpose. It is a float and a filter for the assimilatory current both in the folded and the expanded conditions ; it is an anchor when it is folded. When the funnel is folded, it does not allow any obnoxious object to enter the mouth and I have observed that certain big particles of carmine stuck to the under side of the float and were thus prevented from entering the funnel and consequently the mouth. As a float this apparatus is in all probability not so much used for floating lightly over the surface of floods, as for helping the animal in using its lungs as a hydrostatic organ. To tide over floods the animal probably sticks among weeds or hides under stones and uses the oral apparatus as an anchor.

DIFFERENT TYPES OF ADHESIVE APPARATUS IN FISH AND TADPOLES.

Two types of adhesive organs are found among the fish and tadpoles of mountain torrents, (1) a rounded or elliptical structure with a large callous portion in the centre and a loose membranous flap all round it, (2) an organ composed of grooves and ridges. The former occurs among fishes in the members of the genus *Garra* and in certain tadpoles of the section Ranae Formosae and is found on the under surface of the head slightly behind the mouth. The mechanism[1] of the sucker of this nature has already been described in detail and it has been found by observations in the Khasi Hills that an adhesive apparatus of this nature is quite efficient. The experiments were performed on the living tadpoles of *Rana afghana*. A tadpole was held by its tail and was then placed on a loose piece of stone in the water. The animal was then lifted out of the water by the tail and it was found that the stone was also lifted along with the tadpole. By repeating this experiment with stones of different sizes, it was found that a tadpole weighing 0·1 oz. could easily lift a weight of 5·8 oz. out of water. The animal in this position could be held in the air for a considerable time. A tadpole could lift a stone in this way many times without any apparent harmful effect either to itself or to its adhesive disc. The diameter of the disc is roughly two-fifths of an inch and theoretically a rounded perfect sucker of this dimension ought to lift a weight of about two pounds, since normally there is an atmospheric pressure of about 15 lbs. to a square inch.

The second type of adhesive apparatus consists of striated folds of skin, which may be developed anywhere on the under surface anterior to and including the ventral fins. Usually it is found either on the chest or the anterior ray or rays of the paired fins. The grooves are open at both ends and it is not possible to create a vacuum inside them either by raising the ridges or by depressing the grooves. Moreover, I have not been able to find any muscles which by their action could elevate the ridges or depress the grooves—a condition essential for the creation of a vacuum or a series of vacua. The apparatus is very much like that of *Remora* and *Echeneis*, the so-called ship-holders, though it is situated on a different part of the body and has had a different origin. The "sucking-fishes" have been known from a very early time, but the mechanism of their "suckers" has not been thoroughly studied. The only explanation that has been advanced, and passively believed in by several writers, is that by means of their discs the "sucking fishes" are "enabled to attach themselves to any flat surface, a series of vacua being created by the erection of the usually recumbent lamellae."[2] It is strange that an animal which was so well known to the ancients and has been so ably studied from several different points of view by modern ichthyologists has received little attention in reference to the actual mechanism of its highly interesting organ, the so-called "sucker."

The "sucker" of the ship-holder consists of an oval pad-like area on the top of the head. The integumental edges of this pad are smooth and form a rim, which in well-preserved specimens does not project above the level of the rest of the pad, while the central portion is composed of grooves and lamellar ridges. The free recumbent borders of the lamellae are provided with definite rows of minute but strong spines, all of which point backwards, so that when a finger is passed over them from

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[1] Hora, *Rec. Ind. Mus.* XXIV, pp. 46 (1922).

[2] Günther, *An Introduction to the study of Fishes*, p. 460 (Edinburgh : 1880).

before backwards only a roughness of the surface is felt, but when a finger is passed over the disc from behind forwards the spines obstruct its course and the recumbent lamellae are raised. The grooves between the lamellae open outwards and it appears that water can have free access in and out of them at the edges of the disc. Close to the rim of the pad, the lamellae consist of thin smooth membranes, which might possibly act as valves and allow water to be squeezed out of these grooves and then obstruct its passage in a reverse direction when the fish was fixed to a solid object, but we have no evidence of this. If these valves are capable of acting in the way indicated, it is only then that a series of vacua could be created by the erection of usually recumbent lamellae. But to elucidate any such pehnomenon, extensive observations on living fish would be necessary and I have as yet had no opportunity for the study of the living *Remora.* Preserved specimens in a museum cannot help us much in this interesting problem.

There is one point, however, which negatives the sucker theory and throws some light on the mechanism of the disc of the *Remora.* It has been recorded by several fishermen, sailors and naturalists that a sucking fish is easily detached from its hold by thrusting it forwards or sideways and that it is difficult to disengage it by pulling it back by the tail. In the case of a vacuum sucker it ought to have been immaterial whether the fish was thrust backwards or forwards. I have myself observed that a tadpole of *Rana afghana* held equally fast to the stone irrespective of the part of body from which it was pulled. The very fact that a sucking fish can be easily removed from its hold by thrusting it forwards indicates that its so-called sucker is not a vacuum sucker at all. The spines on the lamellae can only function when the fish is drawn backwards and the greater the force with which it is drawn the more they will be able to penetrate, up to a certain limit, in the soft tissues of a shark or a whale and the pad will be rendered more efficient. Even when the fish is sticking to some hard object, the spines are able to assert themselves more favourably into minute crevices when the animal is pulled backwards. Dahlgren and Kepner's[1] statement that the "greatest suction occurs when the fish is drawn backwards, as by the motion of its host or otherwise. The projecting plates then tend to rise and thus create a vacuum under the pad which is made to adhere the firmer" confirms the explanation advanced above, rather than these authors' own theory.

I submitted specimens of *Pseudecheneis sulcatus* to Prof. C. V. Raman, the distinguished physicist of the Calcutta University, and requested him to enlighten me as to the mechanism of the "sucker" of this fish. He has suggested that the adhesive apparatus of *Pseudecheneis* is more or less a mechanical device to increase friction and that in the discharge of its function it corresponds to the various patterns of ridges and grooves daily observed on motor and cycle tyres. He has, moreover suggested that the formation of vacua in the grooves, if not totally impossible, is of secondary importance. I am greatly indebted to Prof. Raman for this valuable suggestion.

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[1] Dahlgren and Kepner, *Principles of Animal Histology*, p. 415 (New York: 1908).

The striated adhesive apparatus of the hill-stream fishes, from the very nature of their position and the material from which they are evolved, are not so strongly built as the adhesive pad[1] of the "sucking fish." The strong macroscopic spines of the disc of *Remora* or its ally *Echeneis* are, however, analogous to the minute microscopic spines in ths adhesive tissues of the hill-stream fishes[2]. Besides these spines ith greater portion of the under surface of these fishes is provided with papillae which are studded with epidermal spines These papillae are most numerous near the anterior end, where the force of water striking against the fish is greatest. Roughness of the skin increases friction and makes the under surface of the fish less slippery. The almost universal occurrence of this second type of adhesive apparatus in fishes of mountain torrents suggest that it is more efficient than a vacuum sucker. This belief is still further strengthened when it is remembered that species of *Garra*, which live in very rapid water, possess a kind of a striated apparatus on the anterior rays of the paired fins as well as a mental sucker Further study of the mechanism of these two types under the influence of swift currents will go a long way in solving this problem.. I have as yet been unable to discover any action of the extremities of the ridges on the organ of *Pseudecheneis* analogous to that suggeested above as a *possibility* in those of the organs of *Remora* or *Echeneis*.

A vacuum sucker of certain dimensions under atmospheric pressure has a certain limited capacity irrespective of the magnitude and the direction of forces acting to break it. The disc of *Garra* and that of the tadpoles, of Ranae Formosae are not merely suction devices, but their free margins beset with numerous papillae and spines are friction contrivances also. In the case of a striated apparatus the greater the magnitude of the forces acting on it in a particular direction (the fish heading up stream) the greater will be the power of friction developed, since friction depends on the co-efficient of friction and on the pressure. Representing this law in the shape of a formula we will have

$$f = up.$$

where u is the co-efficient of friction, p the pressure and f is equal to the resulting friction. The co-efficient of friction in the striated apparatus is increased in several ways, *i.e.*, by throwing the skin in folds and ridges, by developing minute spine-like epidermal outgrowths and lastly by the papillae, etc. When the co-efficient of friction is very high to start with, a slight increase in p will give a very high value of f. In the case of the hill-stream fishes p is represented by the rapidity of the flow of water and the consequent force exerted by it on the fish. In these fishes, therefore, we have a device by which friction is automatically increased with the rate of flow of water. In the case of *Echeneis* similar force is exerted by water when its host moves about. In this fish the profile of the under surface of the head is modified in exactly the same manner as the dorsal profile of the hill-stream fishes.

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[1] For structure of the disc of *Echeneis* see Storms in *Ann. Mag. Nat. Hist.* (6) II, pp. 67-76 (1888).

[2] Hora, *Rec. Ind. Mus.* XXIV, p. 47 (1922).

As has already been pointed out the adhesive pad of *Echeneis* is strongly built and is highly muscular. There are definite muscles which by their contraction elevate the lamellar ridges bearing spines. It has been supposed that the muscles in this operation "cause a rather weak suction to take place."[1] In my opinion the elevation of the ridges by a muscular action under the control of the animal is for a totally different purpose. I believe that by raising the lamellae, the spines, which originally are directed backwards and are, therefore, able to hold fast to the host, are turned almost at right angles to the surface of the host and thus allow the fish to slip off. This is, in all probability, a device by which the fish can disengage itself even when its host is moving rapidly. I have not found any muscles which operate to "elevate the edge of the whole pad" as has been described by Dahlgren and Kepner (*loc. cit.*). In the histological structure of the pad there is not much of special interest.

MECHANISM OF RESPIRATION IN HILL-STREAM FISHES.

In a paper[2] on the "Structural Modifications in the fish of Mountain Torrents" recently contributed to the *Records of the Indian Museum*, I expressed my views on the probable mechanism of respiration in certain highly specialized fish of small hill-streams. It was then pointed out that with the flattening of the under surface for purposes of adhesion, the gill-openings are more and more restricted to the sides and in extreme cases appear as small apertures above the base of the pectoral fin. Judging from the general build of these fishes, I then thought that normal respiration, which is effected by rhythmical suction of water into the oral cavity and its consequent expulsion through the gill clefts, was almost impossible in those forms which use their lips and mouth as suckers for adhering to rocks and stones in rapid waters. In certain other freshwater fish accessory respiratory organs exist, but depend for their functioning on the fact that the fish, in which they occur are capable of taking in air through the mouth. Such a course is not likely in fishes of mountain torrents for two reasons, firstly because the mouth is on the under surface considerably behind the tip of the snout, and secondly, because such fish live on the bottom with their lower surface adhering to rocks and never come to the surface of water. The air-bladder in some forms is used as a respiratory organ, but in all hill-stream species with which I am acquainted it is greatly reduced and is not capable of taking on this function. It has been observed by Jobert[3] that in certain species of the South American freshwater genera of Siluridae and Loricariidae intestinal respiration occurs, but in the case of Indian and Malay hill-stream forms I have not been able to find any special intestinal respiratory mucous membrane and the experiments recently carried out by me in the Khasi Hills point to the conclusion that anal respiration does not occur. It was suggested in my former paper (*loc. cit.*) that certain inner rays of the paired fins, which sometimes show

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[1] Dahlgren and Kepner, *Principles of Animal Histology*, p. 415 (New York: 1908).

[2] Hora, *Rec. Ind. Mus.* XXIV, p. 42 (1922).

[3] Jobert, *Ann. Sci. Nat.* (Zool.) (6) V, art. 8, pp. 1-4 (1877); *C. R. Acad. Sci Paris* LXXXIV, pp. 309, 310 (1877).

peculiar to and fro movements, were used in oxygenating the blood. Since then I have examined microtome sections of these rays and do not find any special vascular tissue in them. They cannot, therefore, be directly used as respiratory organs.

The gills, in all the hill-stream fishes that I have examined, are well developed and the gill-cavity appears to be relatively larger than that in ordinary fishes. From what I have already said there seems to be no doubt that the gills are the only means of respiration in, at any rate, most of the fish that live in the mountain torrents of the Oriental Region. Water in the hill-streams is generally clear and, as has been shown above, contains more air in solution than still water. The rate of "breathing" may in consequence be very slow, since it has been found that "deficiency in oxygen in the water accelerates the respiratory movements, and the Fish appears to "pant" or breathe hurriedly."[1] Moreover, it has been determined experimentally by Ege and Krogh[2] that the quantity of oxygen absorbed by a fish is greatly reduced when the temperature of the water in which it is placed is lowered. The low temperature of the hill-stream water is thus a distinct advantage to the fish inhabiting it. In these circumstances a small gill-opening may be directly useful for retaining water in the gill-chamber for a longer period. But the main point to be considered is :— How is water to get in and out of the gill-cavity in those forms which are greatly flattened and use their lips as suckers ? It has been pointed out by Regan[3] in his monograph of the Fishes of the Family Loricariidae that when these forms fasten themselves to stones by means of the sucker-like mouth "respiration seems then to be effected by taking in water through the gill-openings and expelling it out by the same passage in a reverse direction." I was prepared to find the same phenomenon in the Indian fish, but my recent observations on several highly specialized forms have rendered this view untenable so far as they are concerned.

A few living specimens of the genera *Garra* and *Glyptothorax* were brought to the Cherrapunji dâk bungalow from the Nong-priang stream and their respiratory current was studied with the help of carmine powder. It was observed that the fish were breathing in the normal way and that the carmine powder was never taken in through the gill-openings. It was also observed after some time that the specimens of *Glyptothorax striatus* lay quietly at the bottom and did not appear to be breathing at all. As the results of the observations were quite contrary to my expectations, I decided to go down to the Nong-priang stream myself and observe the behavior of the fishes as they were taken out fresh from the stream. Most of the day was occupied in the journey to and back from this stream, which lay 3,000 feet below my residence, but during the short time that I could spend on the stream I was able to satisfy myself that normal respiration was the usual course in these fishes. I took observations on *Balitora brucei* and *Pseudecheneis sulcatus* in addition to the species of *Garra* and *Glyptothorax*. Next day I sent for some of these fishes alive to the dâk bungalow and kept them under

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[1] Bridge, *Camb. Nat. Hist.* VII, p. 288 (1904).

[2] Ege and Krogh, *Intern. Rev. Hydrobiol. u. Hydrogr. Leipzig* VII, pp. 48-55 (1915).

[3] Regan, *Trans. Zool. Soc., London* XVII, p. 191 (1904).

observation for a fairly long time. I will now describe the respiratory movements of the various species in detail.

A living specimen of *Glyptothorax striatus* was transferred at about midday to a small glass dish full of clear and fresh water. This fish had been subjected to all the hardships and joltings of an upward journey of 3,000 feet from its natural habitat. At first it appeared to be breathing hurriedly or "panting", but after about half an hour its respiratory movements slowed down and became apparently normal. There was no doubt that it was breathing through the mouth, which remained open throughout and showed very little movement of the lips. The movements of the gill-flaps were somewhat irregular and soon attracted my attention. It was found that as a rule a small upper portion of the gill-cover was moving to and fro and carmine solution came out through this portion only. The remaining portion of the flap remained tightly pressed to the head and did not allow any water to flow out. But every now and then, at irregular intervals varying from 1 to 20 movements of the upper flap, the portion of the gill-cover at the side of the head immediately above the base of the pectoral was lifted and the carmine solution was blown out through the whole of the upper part of the gill-openings with greater force than usual. During this movement, which was of the nature of a deep breath, the portion of the skin between the eye and the nostril was raised considerably upwards.

In members of the genus *Glyptothorax* the gill-openings are fairly wide and those of the two sides are separated by a narrow isthmus on the under surface, but for the purpose of respiration the aperture is divided into three portions, (1) a small upper portion which by its continuous flapping guides the expiratory current. This portion is provided with a well-marked, broad membrane; (2) next is the portion between 1 and the base of the pectoral fin. This only opens when the fish takes a deep breath and throws out any undesirable particles that may have entered the gill-cavity. (3) The last portion is represented by the slit on the under surface of the body and is never opened for respiratory purpose. In fact it is, so far as I can see, merely vestigial and is of no use to the fish. During the time these observations were being taken, the glass dish containing the fish was placed on corks which were resting on a mirror. Thus I was able to watch the fish both from above and from below at the same time.

The fish went on breathing in this way for some time, but after an hour it suspended its respiratory movements altogether and lay quietly at the bottom, only flapping its gill-covers after long intervals and passing out a cloud of carmine, which floated near the mouth, from the upper part of the openings. Eventually even this movement stopped and the fish showed no signs of life. It was still alive at dusk but was found to be dead when I got up next morning.

The essential features of the respiratory movements of a young specimen of *Garra lissorhynchus* were similar to those of *Glyptothorax striatus* as detailed above. This fish is not greatly flattened and its suctorial disc is behind the mouth and quite independent of it, consequently the lips were found to assist in the inspiratory current. The anterior portion of the head was slightly elevated above the surface on which the fish was resting to allow water to get into the mouth. The fish did not suspend breathing even for a few minutes. The gill-opening in this genus does not extend on to the under surface and is specialized into two portions only, corresponding to portions 1 and 2 of that of *Glyptothorax striatus*. The behaviour of these parts of the opercular margin was similar to that described for *Glyptothorax*.

The respiratory movements of *Pseudecheneis sulcatus* were of a different nature. For most of the time the fish was breathing quite regularly and though its gill-covers were specialized into two portions, the lower was never used during respiration. Whenever any undesirable particles such as sand grains entered the mouth, it coughed them out of the mouth and then moved away from them. The fish was, however, capable of suspending its respiratory movements altogether for a fairly long time and under such conditions it lay quietly at the bottom with its sucker-like mouth attached to the substratum.

In certain respects the mechanism of respiration in *Balitora brucei* was similar to that observed in *Pseudecheneis sulcatus*. When any undesirable object entered the buccal cavity with the inspiratory current, the fish always coughed it out with considerable force, so that the object was thrown away in front of it for a distance of an inch or so. Spouting movements of this nature have been observed by Mines[1] in *Torpedo ocellata*, but his conclusions are not borne out by my observations, at least in the case of *B. brucei*. He says that "external stimuli will readily effect the reflex mechanism, but it appears that when external conditions are kept as uniform as possible the periodicity of the spouting movement is determined by the central nervous system." In *B. brucei* the spouting movement only occurred when some external stimulus was given to the fish. I kept a cloud of carmine floated near the tip of its snout for a considerable time, but could not find any regular spouting movement. Some light objects were also kept floated close to the anterior end of the fish, but without any definite result. In this species, as in others, only a small upper portion of the gill-cover was used in the process of normal respiration, and when the fish was lying at the bottom its snout was slightly raised above the level thereof. It seems quite probable that the inner rays of the paired fins, which show peculiar movements, are used in driving away the excess of water that may enter below the fish from the anterior end. In still water these rays stop moving to and fro, thus showing that it is only in rapid water that their movements are useful to the fish. By continuously pumping out the leakage water from underneath the fish they are directely helping the adhesive surface in the performance of its function. There is a regular channel at the base of the pectoral fin along which the water moves before it is expelled at the posterior end and a current flowing in this groove can be seen by placing a few drops of carmine solution near the anterior end of the base of the pectoral fin. It appears that even when the fish is tightly pressed to stones in rapid water a certain amount of the fluid enters underneath the fish from the anterior end.

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[1] Mines, *Proc. Phil. Soc. Cambridge* XVII, pp. 170-174 (1913).

Part of this leakage water is used up in respiration and the remainder is driven out by the action of the inner rays of the paired fins.

Greater specialization in the same direction appears to have taken place in the fishes of the genus *Gastromyzon*, which inhabit the torrential streams of the Indo-Australian Archipelago. In this form the whole of the under surface anterior to and including the ventral fins forms one broad sucker and it appears from an examination of the fish that there is little chance of leakage from the anterior end. The gill-openings are greatly reduced and it seems quite probable that the process of respiration is not continuous. I have not examined the unique species in a living condition, but am of opinion that it is capable of taking fresh water into the gill-chamber only when it darts from one rock to another, and can retain it in the cavity of the gills for a very long time. During the time in which it sticks to stones the movements of the gill-covers are probably suspended altogether. It is hoped that in the near future some one will be able to enlighten us about the mechanism of respiration in this highly interesting fish.

Before proceeding to a totally different type of mechanism it seems worth while to summarize here what has been said above. It has been observed that the Indian hill-stream fishes breathe in the normal way by taking in water through the mouth and passing it out of the gill-openings, and that they are capable of suspending their respiratory movements for a considerable time. When the respiratory movements are suspended, a certain quantity of water is retained in the gill-cavity and the oxygenation of the blood, in all probability, goes on as usual. There are two factors which help fishes in this process, (1) the relatively greater amount of gaseous matter dissolved in the waters of the hill-streams and (2) the low temperature of these waters, which enables the fish to live on a small quantity of oxygen. The reduction of the gill-opening is also a distinct advantage in so as the fish is enabled to retain water in the gill-cavity for a much longer period. It has also been observed that in the event of any undesirable particles entering the buccal cavity, *Pseudecheneis* and *Balitora* throw the particles out of the mouth, while *Garra* and *Glyptothorax* pass them through the gill-openings by taking a deep breath. *Balitora* coughs out obnoxious particles with great force, but *Pseudecheneis* does so more gently and then moves away.

The modifications undergone by the gill-cover and the gill-opening are very interesting and bear repetition. In normal forms the gill-cover consists of a bony part and a membranous border attached to its free end. In hill-stream fishes the membranous flap is fully developed only near the upper corner of the opening, where by its movements it controls the flow of the expiratory current. The part of the gill-cover below this membrane is bony with a narrow membranous margin. By reducing the membranous flap of the bony gill-cover the organ is rendered more capable of fitting tightly against the bones of the pectoral girdle.

The gill-cover is differently modified in an Indo-Malayan Cyprinoid genus *Gyrinocheilus* and consequently the method of "breathing" is quite different from what we have been discussing above, and is indeed unique among bony fishes. To a casual observer there appear to be two gill-openings on each side, a small superior one without an external membranous flap, and a large inferior one with a broad, loose membranous flap attached along the posterior border of the bony gill-cover. The superior aperture forms a vertical slit and on its lower aspect makes a deep notch in the opercular bones. The inferior aperture is similar to that found in other hill-stream fishes, with this difference, that it possesses a broad membranous flap. If the gill cover be lifted with a needle sufficiently high to see the gills, it will then be observed that in reality the two external openings represent two modified portions of the single primary gill-opening with which we are familiar in other fishes. It will also be seen that there is in reality a continuous flap from the upper corner of the superior cleft to the point at which it joins the isthmus. What has actually happened is, that the upper part of this flap has been turned inwards into the cavity and forms a valve inside the upper cleft. The portion where the flap is involuted seems to shut off a small chamber into which the superior aperture opens. This chamber runs straight down to a considerable depth and the branchial arches opposite it are not provided with long filaments. In its position and appearance the superior cleft corresponds to the spiracle of Elasmobranchs and of certain Ganoids, as has been pointed out by Vaillant.[1]

The mechanism of respiration for *Gyrinocheilus* has already been fully described by Vaillant (*loc. cit.*), the author of this interesting genus. It is effected thus :– when the oral cavity is enlarged by the lateral expansions of its walls, water, instead of entering through the mouth as is normal, rushes in through the upper gill-slit. The lower slit does not allow water to enter the gill-cavity as its loose membranous flap is pressed against the side of the body by hydrostatic pressure. The valve of the superior opening being inside, the slit gives way to the rush of water and allows the water to run straight to the buccal cavity. When the action is reversed, the water passes through the gill-clefts and comes out through the lower gill-opening, the upper being closed by the valve owing to the pressure from inside. Thus there are regular inhalent and exhalent apertures, the actions of which are controlled by the modified membranous flap of the gill-cover, which acts as a valve. The mechanism of respiration is similar to that found in Lamellibranch molluscs, in which inhalent and exhalent apertures are situated close together, and in some are separated only by a loose fold of skin. In the mollusc, however, the action of these apertures is not controlled by valves, but by the strong ciliated cells which line the cavities. A somewhat similar method is found among vertebrates in Cyclostomes, in which, as Bridge (*loc. cit.*) describes, "the inspiratory current enters the external naso-pituitary aperture and reaches the pharynx through the naso-pituitary canal and thence, as an expiratory stream, traverses the gill sacs on its way outwards."

MODIFICATIONS IN THE INSECT LARVAE OF MOUNTAIN TORRENTS.

The adaptations exhibited by insect larvae for life in rapid streams are analogous to those described for fish and tadpoles of similar habitat.

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[1] Vaillant, *Notes Leyden Mus.* XXIV, p. 108 (1902).

The similarity consists chiefly in the modification of the external form and in the development of organs of adhesion. In these respects the resemblance is so close that it affords a wonderful illustration of the phenomenon of parallel evolution of the type which has been termed by Dr. Annandale and myself as "communal convergence."[1] It is not my intention to go into details as I know that Dr. G. S. Dodds in collaboration with Mr. F. L. Hisaw intends to publish a series of papers dealing with adaptations to rapid water in may–, caddis– and stonefly larvae. Dr. Dodds has, moreover, informed me that he will shortly be sending his paper on the "Adaptations of May-fly Nymphs to Swift Streams" to press. A short synopsis of this paper has already appeared in the *Proc. Amer. Soc. Zool.* in *Anal. Record* XXIII, p. 109 (1922) and in the September number of the *Journ. Roy. Microsc. Soc., London,* p. 281 (1922). The abstract is in itself a valuable contribution and I take the liberty of reproducing it here from the latter journal.

It runs :— "The following methods of retaining position in rapidly flowing water have been observed in may-fly nymphs :— (1) Swimming species of fish-like (stream line) form swim well in still water, and the stronger swimmers invade the less swift portions of streams. (2) Species of fish-like form and small size have evolved strong legs with which they cling to rocks in the swiftest parts of the torrential stream. (3) Flattened forms retain their position by (a) avoiding the direct shock of water ; (b) flattening of head and legs in such an attitude that the force of water presses the animal against the substratum ; (c) The acquisition of sucking organs, developed from gills on the ventral surface of abdomen ; (d) development of strong legs ; and (e) taking to crevices and thus avoiding currents"

During my recent visit to the Khasi Hills I made a small collection of may-fly and dragon-fly larvae in a small stream below the dâk bungalow at Dumpep. Some of these were taken from bare rocks in fairly rapid water. Those from the latter locality are greatly flattened and are *Balitora*-like in build. The segments of the legs are greatly flattened and are provided with small spines along the lower border and long setae along the upper. In preserved specimens the legs are pressed to the sides of the body with their greatest depth lying in a vertical plane. The ventral surface is also greatly flattened, but no special organs of adhesion have been observed on any part of the body. The lines of demarcation of the various segments of the body serve, in all probability, to increase friction just as the ridges and grooves do in the adhesive disc of *Pseudecheneis* referred to above. The lower shield of each segment is not in any other way specially modified.

I have examined other larvae of Ephemeridae and Perlidae in the collection of the Indian Museum and have found several points of interest in them. In the species that inhabit swift currents, the body is greatly flattened (see Eaton, pl. lviii) but in no case was it so highly modified as in the European Ephemerid genus *Prosopistoma.* "*Prosopistoma* is exceptional in having the body oval in outline, convex above and flattened beneath ; and it possesses the faculty of adhering firmly

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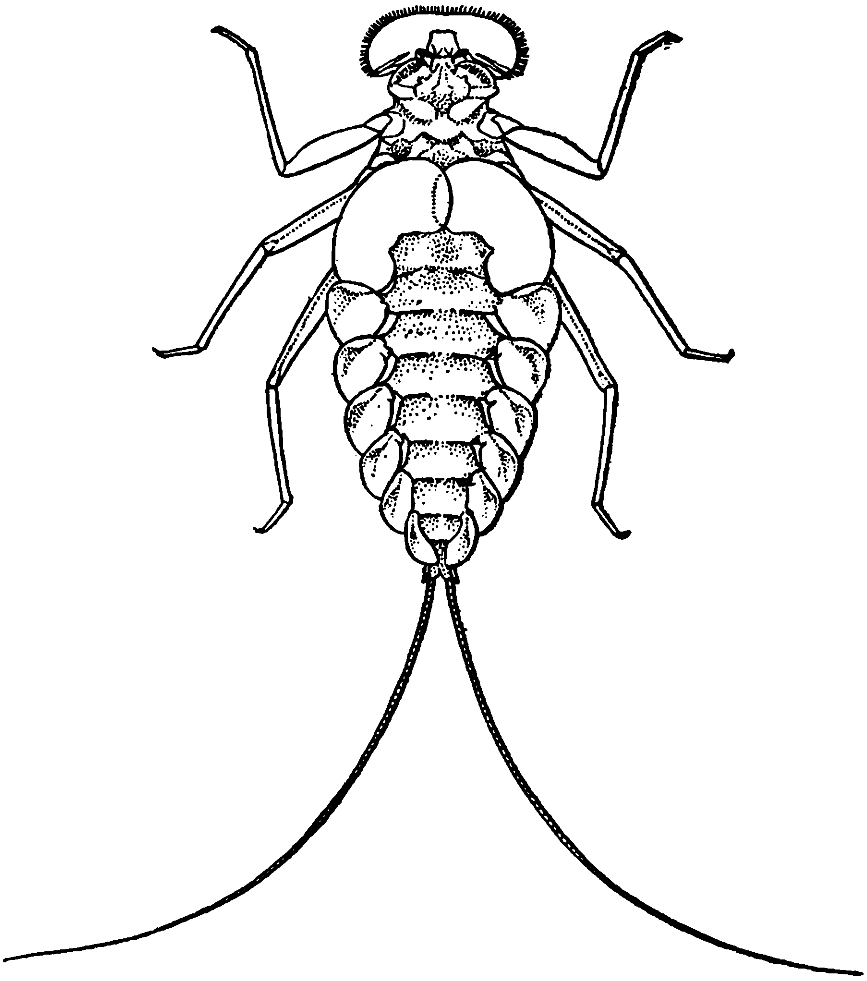
[1] Annandale and Hora, *Rec. Ind. Mus.* XXV, p. 508 (1922).

by suction, like a limpet, to stones."[1] Nor have I examined any nymph in which pectus and venter are provided with densely pilose, adhesive concavities such as are described by Eaton in a North American ally of *Ephemerella*. Among the Indian nymphs there are some which possess adhesive pads on the ventral aspect of the tracheal branchiae. The pads are provided with microscopic spines developed from the outer layer of cells similar to those described and figured by me in a former paper on the adhesive organs of fishes.[2] In certain other nymphs the tracheal branchiae are disposed in such a way (see Eaton, pl. iv, fig. 2) that the whole of the under-surface is rendered capable of acting as a single broad suctorial disc. In this respect these nymphs remind one of the broad and extensive disc of the fishes of the Homalopterid genus *Gastromyzon*.



TEXT FIG. 3.—Ventral view of a Perlid nymph from the Eastern Himalayas, showing the arrangement of tracheal branchiae to form a broad sucker. The dotted areas on the branchiae indicate the position of the thickened spinous pads for adhesive purposes.

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[1] Eaton, *Trans. Linn. Soc., London* (2) III, p. 13 (1883).
[2] Hora, *Rec. Ind. Mus.* XXIV, p. 47 (1922).

APPENDIX.

Quantity of Air dissolved in various waters with an account of the apparatus used in its determination.

It has already been pointed out in the general account that one of my objects in going to the Khasi Hills was to study experimentally the quantity of gaseous matter dissolved in the water of hill streams. As the laboratory of the Zoological Survey of India is not fitted up for carrying out physical experiments, I had to content myself with a simple apparatus, which could be easily carried about from place to place. It may, however, be pointed out that the apparatus devised was not suitable for very accurate work, but was just a device to determine roughly the quantity of air given out by a definite amount of water when heated to a certain temperature. The apparatus consisted of a long-necked flask fitted with a rubber stopper having two holes. A thermometer and a thrice bent tube were tightly fitted into these holes. The flask and the bent tube were then filled with water and the stopper was fitted into the flask in such a way that no air was allowed to pass either into the flask or into the bent tube. The free end of the tube was dipped under water in a dish and the flask was placed on a tripod. A graduated tube filled with water was inverted over the free end of the bent tube and the water in the flask was heated to the desired temperature. In the beginning of the experiment all the air in the flask, the bent tube and the graduated tube was replaced by water, but when the water in the flask was heated the amount of the gaseous matter dissolved in it bubbled out and was collected either in the bent tube or the graduated tube. Thus the amount of air driven out was easily calculated.

The following table gives the results of experiments conducted to determine the quantity of air dissolved in the water of various streams. The quantity of water heated was 570 cc. and the final temperature 83°C in all cases.

Name of stream.	Initial temperature in centigrade degrees.	Quantity of air given out in cubic centimetres.
Ti-u-jir stream at Cherrapunji (alt. 4,300 ft.)	14	9·25
"	"	9·00
Pung-ka-mem-John stream at Cherrapunji (alt. 4,300 ft.)	"	7·50
"	"	8·00
Pool opposite dâk bungalow at Cherrapunji (alt. 4,300 ft.)	"	8·50
Nong-priang stream below Cherrapunji[1] (alt. 1200 ft.)	"	5·00
"	"	5·00
Brahmaputra river at Gauhati	27	3·20
Hugli river at Calcutta	25	1·60

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[1] Water from the Nong-priang stream was brought up to the dâk bungalow at Cherrapunji and then observations were taken on it. It is unfortunate that I forgot to carry a thermometer with me when I went down to this stream, but it can safely be said that the place was much warmer than Cherra.

FURTHER OBSERVATIONS ON THE MOLLUSCS OF THE PUNJAB SALT RANGE.

By N. ANNANDALE, *D.Sc., C.I.E., F.A.S.B., Director, Zoological Survey of India, and* H. SRINIVASA RAO, *M.A., late Research Assistant.*

Our recent paper on the mollusca of the Salt Range (*Rec. Ind. Mus.*, XXV, pp. 387-398) was founded on a collection made by Dr. Sunder Lal Hora in the part of the range which lies east of the Indus. Dr. Hora has recently visited the districts on both sides of that river and has brought back a much larger collection, which enables us to correct and supplement our former report. He found several species which he did not find on his previous tour. Of these the most noteworthy are the following :—

Bithynia tentaculata (Linn.). In great abundance at Pail, Noshera (Salt Range) and other places on the east side of the rivers; very small but otherwise typical.

Digoniostoma cerameopoma (Benson). Several shells with specimens of *Amnicola* (*Alocinma*) *orcula* (Benson) from places on both sides of the Indus.

Buliminus (*Subzebrinus*) *rufistrigatus* (Reeve). A single shell from the eastern part of the range.

Limnaea gedrosiana A. & P. Several typical specimens from the Namal reservoir on the east side of the Indus.

The existence of *B. tentaculata* and *L. gedrosiana* on the east side of the Indus and south of the Himalayas is remarkable.

A reference to the occurrence of *Vivipara bengalensis* f. *halophila* in the Salt Range should have been given in our former paper. See Annandale, *Rec. Ind. Mus.* XXII, p. 277.

In addition to these species Dr. Hora obtained a large series of living and preserved specimens of the form we called *Eulota pentepotamiensis* and also another of our *Buliminus dextrosinister*, on the variation of which Professor P. C. Mahalanobis contributed an interesting note (p. 399). The former specimens prove that we were wrong as to the position and identity of our so-called *Eulota*, which is a Zonitid after all and identical with *Bensonia jacquemonti* (v. Martens).

The second series of *B. dextrosinister* is of great interest. It comprises a very large number of shells and specimens in spirit, including some from the area west of the Indus. The specimens of this species from some localities on both sides of the Indus seem to be dextral without exception, while among those from other localities sinistral individuals predominate.

Bensonia jacquemonti (von Martens).

1908. *Bensonia jacquemonti* (in part) and *Bensonia wynnii*, Blanford & Godwin-Austen, *Fauna Brit. Ind.* Moll. I, pp. 174-176, fig. 62.
1923. *Eulota pentepotamiensis*, Annandale & Rao, *Rec. Ind. Mus.*, XXV, p. 389, pl. ix, figs. 1-3.

Examination of living and preserved material proves that this is no Helicid, in spite of its shell, while the very large series of specimens now before us shows that our *Eulota pentepotamiensis* is a mere synonym of *Bensonia jacquemonti* and also that there is a complete transition between the two forms included in our synonymy. The confusion arose largely because two quite distinct species have been described under the name *jacquemonti*, viz., Nevill's *kurramensis* and the species here discussed. The anatomy agrees in general with Godwin-Austen's figures of that of *B. jacquemonti* var. *kurramensis*.[1]

The mucus-pore at the apex of the foot is relatively small and has a circular tumid lip but no overhanging process in the living animal. In preserved specimens, however, a process is apparent. In the radula the number of teeth present in a transverse row is fewer than in the type-species of *Bensonia*. The relative lengths of the structures in the distal portion of the genitalia seem to vary according to their seasonal development.

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[1] Godwin-Austen, *Land and Freshwater Moll. Ind.* II, pl. xcv, fig. i (1899),

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