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

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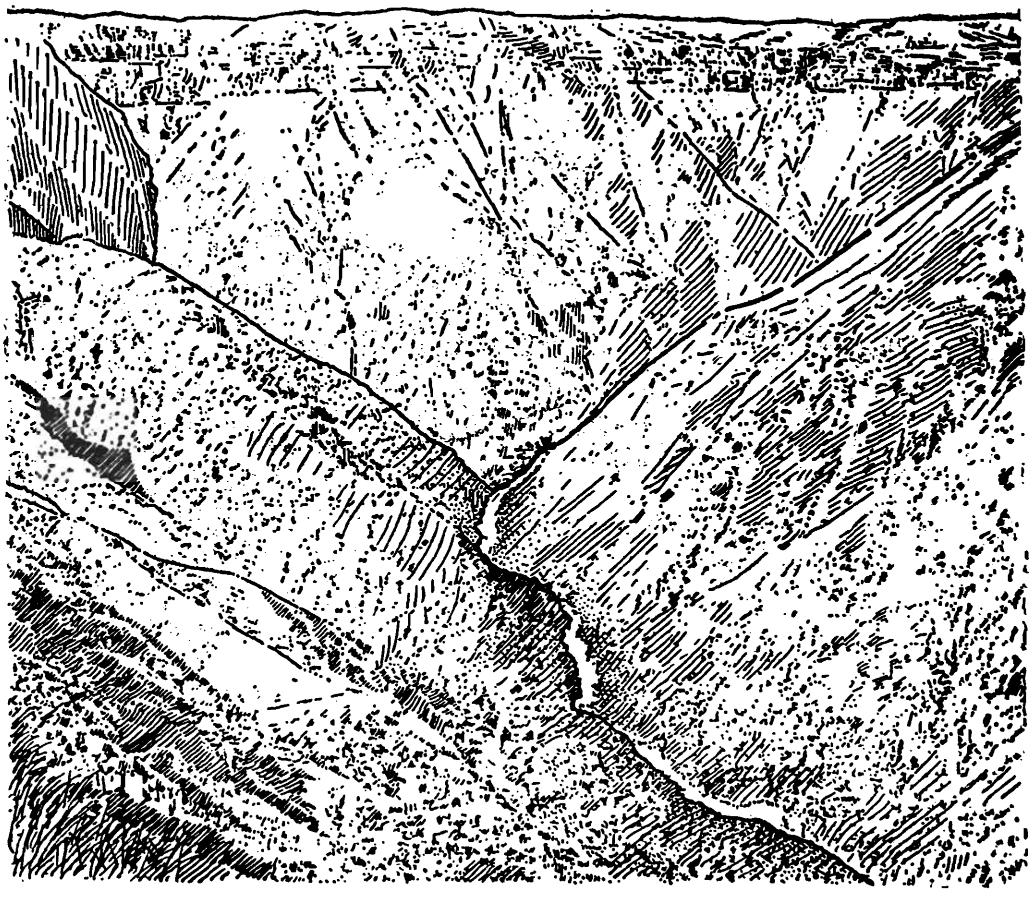
[1] Hora, *Rec. Ind. Mus.* XXV, pp. 4-8 (1923); *Journ. Asiat. Soc, Bengal* (n. s.) XVIII. pp. 9-15 (1921).

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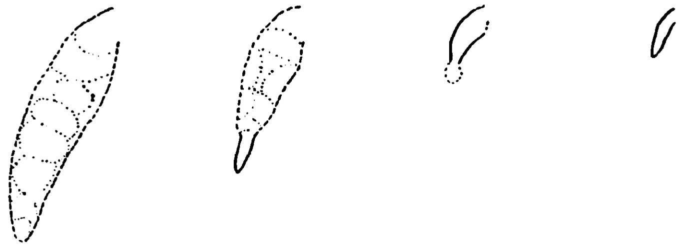
[1] Annandale and Hora, *Rec. Ind. Mus.* XXIV, p. 508 (1922).

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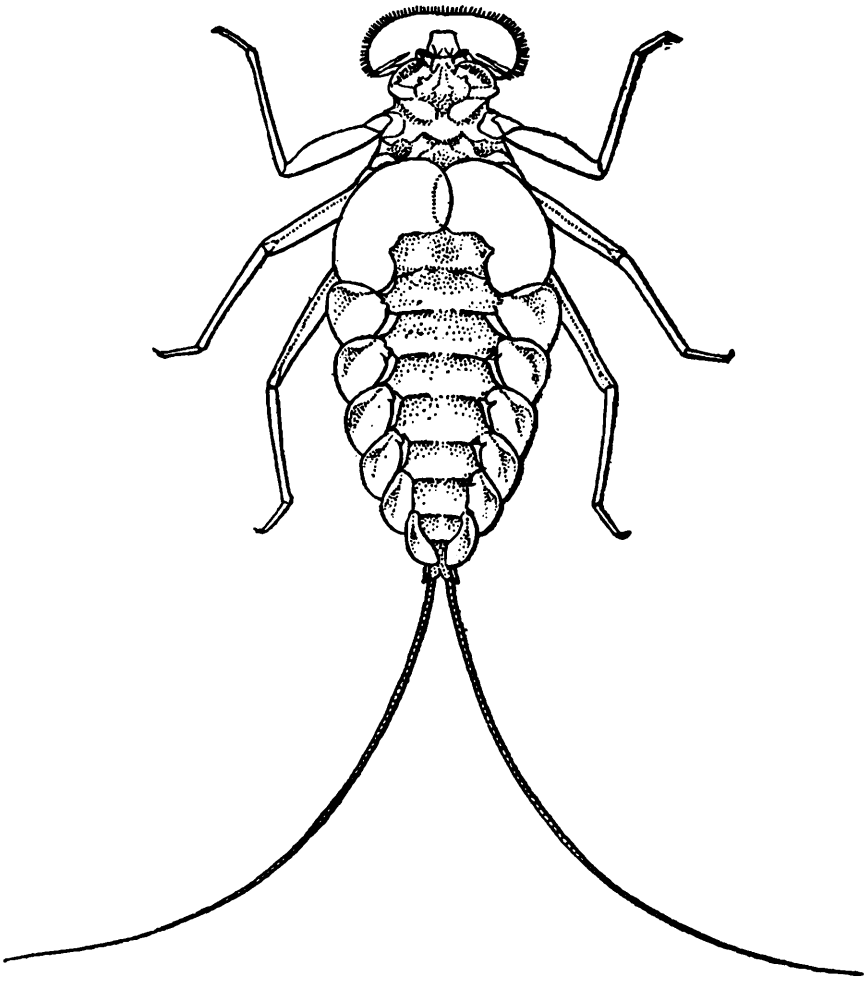
[1] Annandale and Hora, *Rec. Ind. Mus.* XXV, p. 508 (1922).

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.