genus, *V. crassispiralis* to the Viviparae bengalenses and *V. mic-ron* to the Viviparae dissimiles. Each species, however, is quite distinct from any other, as are also *D. textum* and *S. elegantior*, the resemblance between the shell of the latter and that of the Indo-Burmese *S. semiserica* being superficial. The *Patudonum*, on the other hand, is closely allied to *P. conica*, a remarkably plastic Assamese species with many local races, amongst which the Manipur form might perhaps be included.

Considered as a whole the Gastropod molluscs of the ponds, swamps and streams of Manipur are thus remarkable from a geographical point of view in only one feature, in the small evidence they afford of a close connection with those of Burma such as might have been postulated from the fact that the river-system of the Manipur Valley, in which the great majority of them live, is directly connected with the largest tributary of the Irrawaddi and completely isolated from all other systems.

We may now consider the geographical distribution of the bivalve molluscs of Manipur. Among these six genera are represented, *Indonaiia, Lamellidens, Trapezoides, Corbicula, Sphaerium* and *Pisidium*. The first three genera belong to the Unionidae, the last three to the Cyrenidae. As the two families have different means of dispersal and also different limitations in their dispersal, we may consider them separately. The parasitic period in the life of the Unionidae and the fact that the different species are attached to different species of fish in this period give the members of the family a peculiar means of progression from one part of a river-system to another and at the same time correlate their geographical distribution with that of their hosts. We might expect, therefore, that the Unionidae of the Manipur Valley would be more exclusively Burmese than either the Gastropods or the Cyrenidae. Mr. Sunder Lal Hora, who has worked out the large collection of fish he made in Manipur, tells me that he finds among them a large proportion of Burmese species and that he obtained evidence, direct and indirect, that certain species migrate up the Imphal River at certain seasons. That such fish should bring with them from Burma the glochidia of Burmese Unionidae would be what might be expected. But the evidence for this is not very strong. The genus *Trapezoides* is certainly in the main a Burmese and Indo-chinese genus and the only species found in Manipur (*T. misellus*) is a Burmese and Indo-chinese species, but the occurrence of another, hitherto undescribed species (*T. dhanushori*, Prashad) north of the Naga Hills considerably discounts the value of this piece of evidence, though it does not run counter to it. *Indonaiia*, although it has its headquarters in the north-eastern part of the Indian Empire, is by no means exclusively Burmese. Three of the four species found in Manipur have also been found in Assam if not in India proper, and only two of these in Burma, while the fourth is known only from the Manipur Valley.

Even from the Unionidae, therefore, evidence for any but a
recent connection with Burma is by no means strong, and the Assamese and Bengali element in the fauna is clearly shown.

The three genera of Cyrenidae represented in the Manipur fauna are all of exceedingly wide range, *Sphaerium* and *Pisidium* being almost cosmopolitan, while *Corbicula* is found in the warmer parts of all regions.\(^1\) The species of these genera known from Manipur, with two possible exceptions, have a wide range in northern India; the two exceptions being *C. subradiata*, for which the Manipur Valley is the only precise locality recorded, and *S. austeni* which is only known from Manipur and the Naga Hills. Of the others, *C. occidentals* and *C. striatella* occur all over the plains of India, while *S. indica*, *P. clarkeanum* and *P. hydaspica* have been found at considerable altitudes in northern India as well as in widely separated localities in the Indo-Gangetic plain.

The Cyrenidae, indeed, provide as little evidence for long-established connection between the Manipur Valley and Burma as any other family of aquatic molluscs.

To sum up, therefore, the geographical affinities of the aquatic and amphibious Mollusca of Manipur as revealed by the distribution of genera and species, it may be stated briefly that these affinities are rather with the molluscs of Assam and the Gangetic Valley than with those of the valley of the Irrawaddy or the Salween and that the Burmese element is much smaller than might be expected from the close connection between the river-system of the Manipur Valley and of the Irrawaddy.

**Ecological Distribution.**

As might be expected in a swampy valley like that of Manipur, the aquatic fauna is largely paludine. Even in the Loktak Lake there has been no evolution of a true lacustrine fauna, and, indeed, the number of species of aquatic molluscs is comparatively small. The species found actually in the lake are—

*Vivipara oxytropis.*  
*Lecythoconcha lecithis.*  
*Lymnaea acuminata.*  
*Indoplanorbis exustus.*  
*Pisidium clarkeanum.*  
*Gyraulus cantori.*  
*Hippellus (?) umbilicalis.*  
*Lamellodens corrianus.*  
*Sphaerium indicum.*

The majority of these species are common in small ponds in the Gangetic Delta and none of them have been found in a true lake, except *Indoplanorbis exustus*, which in the Inlé Lake haunts only the swampy marginal zone and in the Tałę Sap in Siam is found only among beds of weeds near the shore. The only species that are in any way characteristic of the Loktak Lake are the two Viviparidae. These attain their maximum development only in the deeper part of the swamp, but both are found also in ponds and smaller swamps throughout the valley. No definite zones of life can be recognized here, but *Lamellodens marginalis* and *Pisi-
*dium clarkeanum*, burrowing species, were found only at the extreme edge of the northern part of the lake where the vegetation is less congested, while the third bivalve (*Sphaerium indicum*), which swarms freely among the branches of water-weeds, was most abundant in the deeper parts.

*Limnaea ovalis* probably occurs in the Loktak Lake when it is full as we found it in small pools that would be included at that season, but it is even more of an exclusively paludine species than those discussed as inhabitants of the lake. Indeed, it seems to be almost amphibious in habits and thus from an ecological point of view may almost be classed with *Succinea elegans*, a species found in abundance at the edge of the northern part of the lake.

Only a few species were found in running water, but here it is necessary to recognize a fundamental difference between the rapid-running streams of the hills, with their clear water and stony bed, and the sluggish, turbid rivers of the valley. In hill-streams the only Gastropods commonly observed were *Paludomus pustulosa* and the narrowest phase of *Limnaea andersoniana*. Bivalves were rather more common and included the following species, *Corbicula occidentis*, *Indonaia bonneaudi*, *I. theobaldi* and *I. lima*, all thick-shelled forms, as is also *P. pustulosa*. At least two other species make their way into muddy, comparatively still pools in such streams, viz. *Melanoides tuberculatus* and *Acrostoma variabilis*.

In the larger rivers of the valley the muddy bottom is favourable to these two Melaniidae and also to the thin-shelled Unioidae of the genus *Lamellidens*, while in small, sluggish streams and water-courses *Ancylus viola*, *Limnaea acuminata*, *Corbicula occidentis* and *Pisidium clarkeanum* are sometimes not uncommon. It was in such a streamlet also that we found *Campyloceras lineatum*.

Generally speaking, the species of *Paludomus*, *Acrostoma* and *Indonaia* are inhabitants of running water. *Paludomus* is found as a rule in mountain streams or at any rate in running water near the base of hills and on a stony bottom, while *Acrostoma* and *Indonaia* need mud and therefore less rapid water. As is suggested in Dr. Baily Prashad’s part of this paper, the genus *Lamellidens* can probably be divided into two sections from an ecological point of view, one, which produces very large numbers of embryos and as a rule frequents running water, the other, with a smaller number of embryos, that affects ponds and swamps. These observations, to which there are of course exceptions, are on the whole substantiated in Manipur, but in applying them it must be remembered that conditions in a very sluggish, weed-choked stream often approximate closely to those in a swamp and attract paludine forms.

**Variation and Plasticity.**

It is particularly interesting to contrast the Manipur Valley with that of the Inlé Lake in reference to the variability and plasticity of the aquatic molluscs. As I have pointed out in the Introduction to this paper, the two valleys have certain physical fea-
tures in common, others, which are perhaps more important, widely divergent. Comparatively few species of molluscs are identical in the two localities, and the general facies and composition of the fauna is very different. In the Inlé Valley the two families of molluscs most remarkable for their plasticity are the Viviparidae and the Limnaeidae. As this is also so in the Manipur Valley, it will greatly simplify my comparison if I confine my remarks to these two families. I will begin to do so by drawing up in tabular form the main differences between the Viviparidae of the Inlé Lake and those of the Manipur Valley.

<table>
<thead>
<tr>
<th>Inlé Valley</th>
<th>Manipur Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genus represented</td>
<td>Taia, Lecytoconcha.</td>
</tr>
<tr>
<td>Predominant genera</td>
<td>Taia.</td>
</tr>
<tr>
<td>Number of living species</td>
<td>Taia 5, Lecytoconcha 1.</td>
</tr>
<tr>
<td>Fossil forms known</td>
<td>Four (Taia),</td>
</tr>
<tr>
<td>Number of species with highly sculptured shells</td>
<td>5 recent, 4 fossil (Taia).</td>
</tr>
<tr>
<td>General character of shell-sculpture in such forms</td>
<td>Nodular, squamose or spinose ridges.</td>
</tr>
<tr>
<td></td>
<td>Vivicpara, Lecytoconcha.</td>
</tr>
<tr>
<td></td>
<td>Vivicpara.</td>
</tr>
<tr>
<td></td>
<td>Vivicpara 3, Lecytoconcha 1.</td>
</tr>
<tr>
<td></td>
<td>None.</td>
</tr>
<tr>
<td></td>
<td>2 recent (Vivicpara).</td>
</tr>
<tr>
<td></td>
<td>Smooth ridges.</td>
</tr>
</tbody>
</table>

In considering the meaning of the differences thus summarily expressed we have to take into account not only the differences in environment but also the idiosyncracies of the different genera represented, for there is no fact more evident in the study of the freshwater molluscs than that different genera have different tendencies in the matter of variation and plasticity. At present we have three genera to consider, Vivicpara, Lecytoconcha and Taia. It will be convenient to take Lecytoconcha first.

Although this genus is present in both valleys it is so scarce in the Inlé Valley, and I know so little about it there, that I must confine my remarks, so far as my own observations go, to its peculiarities in Manipur. I have selected this genus as the protagonist in my argument because its case is not complicated by the production of an abnormal and exuberant shell-sculpture. We may indeed, so far as Manipur is concerned, regard Lecytoconcha as a smooth-shelled genus. Further east, especially in Japan, we find shells presumably of this genus with a type of sculpture very like that of Vivicpara oxytropis, but we know nothing of their anatomy and they must for the present be ignored. It is probable that their case is similar to that of the species of Vivicpara already mentioned and to be discussed further.

The one species of Lecytoconcha found in Manipur extends the range of the genus a considerable distance westwards from its
headquarters in China, but it has colonized the Manipur Valley successfully and is at home in practically every part of its waters except in streams and rivers. Its plasticity is remarkable, and has probably aided it in taking possession of a very large territory. In the Manipur Valley we found no less than four phases common, each in its proper environment, and, so far as I know, only one of these phases has been found outside the valley, unless the locality "Sylhet" is correct for the forma typica, which I doubt greatly. Should my doubt prove unfounded it will not alter my argument. Of the four phases the largest and best developed is the one found in the central parts of the Loktak Lake, amidst dense submerged vegetation but in comparatively clean water of relatively considerable depth. The shell in this phase provides less evidence of interrupted growth than any of the others, less individual variation and as a rule a greater symmetry in proportions. It is, indeed, of just such a type as might be expected to occur in conditions in every respect favourable to the species. The only approximation, however, to a true lacustrine type exhibited by it is its comparative thinness. It has no tendency whatever to assume the elongate conical outline of the lacustrine species of Taia. Indeed, it is more globose than the shell of either the phase found at the edge of the great swamp or that found in ponds. The rice-field phase, on the other hand, is still more globose than the deep-water one, but does not possess its symmetry or constancy to type.

It is evident that we are here dealing with plasticity of a somewhat different type from that illustrated by the genus Taia in the Shan States, and with one in which the direct result of environment on the individual may be more safely postulated.

Indirectly the structure and post-embryonic development of L. lecythis cast an interesting sidelight, though the adult shell is smooth or nearly so, on the question of the development of prominent spiral sculpture on the shells of the Viviparidae in certain circumstances, but this point can be discussed more clearly after the facts about Vivipara oxythrops have been summarized.

Of the three species of Vivipara found in Manipur two are very scarce and have not been seen by me in their natural surroundings. The third (V. oxythrops) is, however, abundant and shares with L. lecythis the position of a dominant species throughout the valley. Two points have to be considered in reference to this species, its plasticity and its peculiar sculpture, the latter not so much for its own sake as for the light it throws, taken with certain facts in the life-history of L. lecythis, on larger questions.

V. oxythrops is not quite so abundant or so universally distributed in the Manipur valley as L. lecythis. It is very nearly if not quite as common in the Loktak Lake, but much scarcer in most ponds and practically absent from the smaller swamps. This may perhaps be correlated with two facts, firstly that it is not nearly so plastic (i.e. cannot adapt its external form to different types of environment so well), and secondly that it is so largely parasitized not only by a trematode (Leucochloridium encysted in its mantle,
The importance of *V. oxytropis* in the study of these phenomena only becomes apparent when we compare the structure of its mantle and shell with those of the mantle and shell of *Taia* and contrast the constant character of the Manipur species with the plasticity and variability of such a species as *T. naticoides*. This I have done in another paper\(^1\) in the *Records of the Indian Museum*.

We may now turn to the Limnaeidae of the Inlé and Loktak Lakes. In the former body of water three species have been found, namely *Limnaea shanensis*, Annandale, *L. andersoniana*, Nevill and *L. mimetica*, Annandale. The last is a small and highly peculiar species only known from the Inlé Lake and not exhibiting noteworthy variability or plasticity, except in so far that it is probably as a species the product of plasticity in some form of the *L. acuminata* group. *L. shanensis* is not, strictly speaking, a variable species, and we only know that it is or has been highly plastic through the existence of fossil or subfossil phases. With *L. andersoniana* I will deal presently.

In the Loktak Lake the only species of *Limnaea* collected was *L. acuminata*, but we may consider with it two other species found in swamps or ponds in the Manipur Valley. These are *L. ovalior*, sp. nov., and *L. andersoniana*, Nevill.

*L. acuminata* provides us with one of the best examples of true or individual variability to be found in the genus. In some districts (see fig. 12, p. 569) there is a very great difference in the shape of different shells from the same environment, but this is not so, apart from aberrations or monstrosities, in the Loktak Lake. A slight plasticity, however, is to be found in that individuals from the less congested parts of the swamp have a distinctly smaller shell and a shorter spire than those from the margin, while those from a small sluggish stream in the vicinity have remarkably pale and fragile shells with a strong but irregular external sculpture.

An interesting aberration is represented in our collection by a single specimen. It is remarkable for the very poor development of its spire, a feature common in lacustrine forms of the genus.

*L. ovalior* is known only from the swamps that surround the Loktak Lake and from Dimapur in the plains of Assam, north of the Naga Hills. In the latter locality it was found in a single pool of very foul water. Shells from this situation differ from those from the Manipur swamps in the same way as, but to a greater extent than, those of *L. acuminata* from the more congested part of the Loktak Lake do from those of the same species from its open region.

It is in *L. andersoniana*, however, that plasticity occurs in the most highly developed state. In the Inlé Valley two forms of

---

\(^1\) Vol. XXII, pp. 243–266 (1921).
this species have been found—a broad form in ponds and a narrow form in a small stream. In the Manipur Valley and at Dimapur no less than four such phases occur. Two of these are almost identical with the two from the Shan States and inhabit similar types of environment. A third phase, still narrower than that found in rapid running water in the valley, inhabits higher parts of the same streams, where they have the character of mountain torrents. Perhaps, however, the most interesting phase is that found at Dimapur in small cattle-ponds. It may be described as both intermediate in some individuals between the pond phase and the ordinary stream phase, and also, in other individuals, as a more extreme form of the pond phase. A partial explanation is probably to be found in the fact that the ponds it frequents are connected in the rainy season with small streams. The narrower individuals may be those that have grown up in these temporary streams, while the broader individuals are those that have never left the ponds.

We thus see that whereas the type of plasticity characteristic of *L. andersoniana* is essentially similar in the Inlé and Manipur Valleys, that observed in the Viviparidae is different in kind in the two localities. We do not find any species of mollusc in Manipur that exhibits the extreme variability in shell-sculpture of *Taia naticoides*, in the Shan States, and even in *L. acuminata* variability in shell-form is much less marked in the Loktak Lake than it is in many other localities. In the present state of our knowledge it is as well not to speculate further as to the meaning of these observations.

ADDENDUM.

Note on *Sphaerium montanum*, Tapparone-Caneifri.

Since this paper went to press I have, through the kind offices of Dr. R. Gestro of the Genova Museum, had an opportu-
been unable to include in my revision of the Indian species of the genus Sphaerium (supra, p. 614) owing to insufficient information. As a result of my examination of the unique type I am now able to confirm the author's opinion of his species from Burma being a distinct species. In the Indian Museum I was also fortunate in finding a specimen in Theobald's Burmese collections of Unionidae which is referable to this species. Unfortunately the exact locality of Theobald's specimen is not known.

I have nothing to add to Tapparone-Canefri's description, but give below the measurements of the type-shell and of Theobald's specimen. I have also taken this opportunity to publish a figure of the shell and the hinge-teeth of the type-specimen.

Measurements (in millimetres).

<table>
<thead>
<tr>
<th></th>
<th>Type-specimen</th>
<th>Theobald's specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>8.2</td>
<td>8.1</td>
</tr>
<tr>
<td>Breadth</td>
<td>7.3</td>
<td>7.4</td>
</tr>
<tr>
<td>Thickness</td>
<td>4</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Tapparone-Canefri compared his species with S. indicum, Deshayes, but was doubtful as to its possible identity with S. avanum, Theobald. The species, however, has no relationship with S. avanum, and forms a distinct group with S. indicum and S. austeni. From either of these species it is easily distinguished by its subquadrate shape, less tumid shell, less prominent umbones, which do not project so far upwards and inwards as in the other two species, proportionately larger lateral teeth and in having the two lamellar cardinals of the right valve distinctly separated from each other by a fairly deep notch.

[B. Prashad.]
XXIX. INDIAN CYPRINOID FISHES BELONGING TO THE GENUS GARRA, WITH NOTES ON RELATED SPECIES FROM OTHER COUNTRIES.

By Sunder Lal Hora, M.Sc., Assistant Superintendent, Zoological Survey of India.

(Plates XXIV—XXVI).

Contents.

| Introduction | ... | 633 |
| History | ... | 634 |
| Probable evolution of the disc of Garra, as represented by a series of specimens collected in Manipur, Assam | ... | 630 |
| Skeleton of the mouth-parts | ... | 643 |
| Air-bladder and associated skeletal structures | ... | 646 |
| Garrn and Discognathus | ... | 648 |
| Synopsis of the Indian and some Extra-Indian species of Garra | ... | 649 |
| Part 1. Indian species of Garra | ... | 651 |
| Part 2. On some Extra-Indian species of Garra | ... | 676 |
| Bibliography | ... | 683 |

INTRODUCTION.

Among the Indian fresh-water fishes few have greater interest in the study of evolution than those belonging to the genus *Garra*. Great confusion has prevailed in the taxonomy of this genus, partly because many of the species exhibit considerable individual variability, and partly because ichthyologists have attempted to apply to them specific standards unsuitable for forms apparently still in the process of adaptation to their environment. Scale-counts, number of fin-rays and proportions are all important diagnostic characters in most Cyprinid genera; but in *Garra*, at any rate, they have much less significance than the structure of certain organs and appliances modified or produced in correlation with the peculiar mode of life adopted, apparently not very long ago, by the members of the genus. Before expressing an opinion as to how this has come about it is necessary that the genus should be investigated as completely as possible on anatomical and taxonomic lines. This Annandale attempted to do, so far as the taxonomy of the Indian species is concerned, in two recent papers (1919a, b), while Narayan Rao (1920) has still more recently published a third paper on the same subject and Annandale and I have discussed the generic position of the fish in a fourth (1920).
The great difficulty under which we have laboured hitherto has been that the type-specimens of older species were not available and that the figures and descriptions previously published were inadequate. This difficulty has now been overcome to a great extent, firstly because the old collection of the Indian Museum, including types of the species described by Day, which was sent to Dr. V. Pietschmann before the beginning of war, has been returned to Calcutta, and secondly because I have been able to visit and obtain specimens from the same localities in which Hamilton Buchanan found his specimens of *Cyprinus* (Garra) *lamta*, the genotype of Garra. The collection of the Zoological Survey of India has also been very largely augmented by the addition of specimens from many parts of the Indian Empire, and we have in particular received from Mr. Narayan Rao and Mr. G. E. Shaw, to whom our best thanks are due, valuable series from Coorg and the Darjiling Himalayas respectively. The Bombay Natural History Society has also lent us some interesting forms, and practically all the Indian districts whence specimens of the genus have been described are now well represented in our collection.

My sincere thanks are due to Dr. N. Annandale for placing the valuable material in my hands for investigation and description and for allowing me to visit some hill-streams to study these fishes in nature. I am indebted to Dr. S. W. Kemp for going through the manuscript with me and also for some valuable suggestions. I have also to express my obligations to Mr. Tate Regan for the courtesy he has shown me in sending at my request a copy of Heckel’s original description of the genus *Discognathus*.

**HISTORY.**

Hamilton Buchanan, in his classical work entitled “An account of the Fishes of the Ganges,” published in 1822, was the first to describe a species—*Cyprinus lamta*—with a disc behind the lower jaw, which he “found in rivulets, with rocky bottoms, in the province of Behar, and in the Rapti River of the Gorakhpur District.” This characteristic form he referred to his ninth division of *Cyprinus* which he termed Garra. A decade after this Gray (1832) figured a similar species, *Cyprinus gotyla*, also with a disc on the lower jaw, from “Mountain Stream, India”; while McClelland (1838, 1839, 1842) recorded a number of species with the same character from streams in the Eastern Himalayas. The latter, however, described his specimens under two genera, *Gonorynchus* and *Platycara*, and seems to have attached no importance to the character of the disc. Sykes (1841) also paid little attention to this well-marked structure in *Chondrostoma mulya* from South India and it was left to Heckel to recognise its value as a generic distinction when he referred his Syrian specimens (1843) to the new genus *Discognathus*. Heckel refers to Gray’s species and also to those described by McClelland, but seems to have been unaware of the existence of *Cyprinus lamta* and *Chondrostoma*
1921.] Manipur Molluscs. 623

genus, V. crassspiralis to the Viviparae bengalenses and V. mic-
ron to the Viviparae dissimiles. Each species, however, is quite
distinct from any other, as are also D. textwn and S. elegantior,
the resemblance between the shell of the latter and that of the
Indo-Burmese S. scmiscrica being superficial. The Pcdudomus,
on the other hand, is closely allied to P. conica, a remarkablj’
plastic Assamese species with many local races, amongst which
the Manipur form might perhaps be included.

Considered as a whole the Gastropod molluscs of the ponds,
swamps and streams of Manipur are thus remarkable from a
geographical point of view in only one feature, in the small
evidence they afford of a close connection with those of Burma
such as might have been postulated from the fact that the river-
system of the Manipur Valley, in which the great majority of
them live, is directly connected with the largest tributary of
the Irrawadi and completely isolated from all other systems.

We may now consider the geographical distribution of the
bivalve molluscs of Manipur. Among these si.K genera are repre-
sented, Indonaia, Lamellidens ^ Trapozoideii, Corbiciila, Sphaeriuin
and Pisidiium. The first three genera belong to the Unionidae,
the last three to the Cyrenidae. As the two families have
different means of dispersal and also different limitations in their dispersal, we may consider them separately. The parasitic period in the life of the Unionidae and the fact that the different species are attached to different species of fish in this period give the members of the family a peculiar means of progression from one part of a river-system to another and at the same time correlate their geographical distribution with that of their hosts.

We might expect, therefore, that the Unionidae of the Manipur Valley would be more exclusively Burmese than either the Gastropods or the Cyrenidae. Mr. Sunder Lai Hora, who has worked out the large collection of fish he made in Manipur, tells me that he finds among them a large proportion of Burmese species and that he obtained evidence, direct and indirect, that certain species migrate up the Luiphal River at certain seasons. That such fish should bring with them from Burma the glochidia of Burmese Unionidae would be what might be expected. But the evidence for this is not very strong. The genus Trapezoideus is certainly the main a Burmese and Indo-chinese genus and the only species found in Manipur (T. misellns) is a Burmese and Indo-chinese species, but the occurrence of another, hitherto undescribed species (T. dhamishori, Prashad) north of the Naga Hills considerably discounts the value of this piece of evidence, though it does not run counter to it. Indonaia, although it has its headquarters in the north-eastern part of the Indian Empire, is by no means exclusively Burmese. Three of the four species found in Manipur have also been found in Assam if not in India proper, and only two of these in Burma, while the fourth is known only from the Manipur valley.
Even from the Unionidae, therefore, evidence for any but a

[Begin Page: Page 624]

624 Records of the Indian Museum. [Vol. XXII,

recent connection with Burma is by no means strong, and the As-
samese and Bengali element in the fauna is clearly shown.

The three genera of Cyrenidae represented in the Manipur
fauna are all of exceedingly wide range, Sphaeniu-in and Pisidium
being almost cosmopolitan, while Corbicula is found in the warmer
parts of all regions. The species of these genera known from
Manipur, with two possible exceptions, have a wide range in northern India, the two exceptions being C. suhradi'.da, for which the
Manipur Valley' is the only precise locality recorded, and S. austeni
which is only known from Manipur and the Naga Hills. Of the
others, C occid ns and C striatella occur a'l over the plains of In-
dia, while S. inuiciim, P. clarkeanitm and P. hydaspicola have been
found at considerable altitudes in northern India as well as in
widely sepirate:! localities in the Inilo-Gangelo plain.

The Cyrenidae, indeed provide as little evidence for long-estab-
lished connection between the Manipur Valley)' and Burma as any
other family of aquatic molluscs.
To sum up, therefore, the geographical affinities of the aquatic and amphibious Mollusca of Manipur as revealed by the distribution of genera and species, it may be stated briefly that these affinities are rather with the molluscs of Assam and the Gangetic Valley than with those of the valley of the Irrawadi or the Salwtea and that the Burmese element is much smaller than might be expected from the close connection between the river-system of the Manipur Valley and of the Irrawadi.

Ecological Distribution.
As might be expected in a swampy valley like that of Manipur, the aquatic fauna is largely paludine. Even in the Loktak Lake there has been no evolution of a true lacustrine fauna, and, indeed, the number of species of aquatic molluscs is comparatively small.
The species found actually in the lake are —


Lecythaconcha lecythis. Hippeutis (?) nmhilicalis.

Liinaea ocmninata. Lamellidens corrian-us.

Indoplanorbis exustus. Sphaerium indicum.

Pisidium clarkeanum.

The majority of these species are common in small ponds in the Gangetic Delta and none of them have been found in a true lake, except Indoplanorbis exustus, which in the Inle Lake haunts
only the swampy marginal zone and in the Tale Sap in Siam is found only among beds of weeds near the shore. The only species that are in any way characteristic of the Loktak Lake are the two Viviparidae. These attain their maximum development only in the deeper part of the swamp, but both are found also in ponds and smaller swamps throughout the valley. No definite zones of life can be recognized here, but Laiiellidens marginalis and Pisi-

It occurred in England in Tertiary times.

[Begin Page: Page 625]

1 921. J Maniptir Molluscs. 625

dium clarkeanum, burrowing species, were found only at the extreme edge of the northern part of the lake where the vegetation is less congested, while the third bivalve (Sphacritim indicum), which swarms freely among the branches of water-weeds, was most abundant in the deeper parts.

Linwaea ovalior probably occurs in the Loktak Lake when it is full as we found it in small pools that would be included at that season, but it is even more of an exclusively paludine species than those discussed as inhabitants of the lake. Indeed, it seems to be almost amphibious in habits and thus from an ecological point of view may almost be classed with Succinea elegans, a species found in abundance at the edge of the northern part of the lake.
Only a few species were found in running water, but here it is necessary to recognize a fundamental difference between the rapid-running streams of the hills, with their clear water and stony bed, and the sluggish, turbid rivers of the valley. In hill-streams the only Gastropods commonly observed were Paludomits piistiilosa and the narrowest phase of Limnaea andersoniana. Bivalves were rather more common and included the following species, Corbicula occidens, Indonaia bonneaudi, I. theobaldi and /. lima\(^\d\) all thick-shelled forms, as is also P. pustulosa. At least two other species make their way into muddy, comparatively still pools in such streams, viz. Melanoides tuberculatus and Acrostoma variabilis.

In the larger rivers of the valley the muddy bottom is favourable to these two Melaniiidae and also to the thin-shelled Unioidae of the genus Layndlidens\(^\d\) while in small, sluggish streamlets and water-courses Ancyliis viola, Limnaea acuminata, Corbicula occidens and Pisidium clarkeanum are sometimes not uncommon. It was in such a streamlet also that we found Camptoceras liwatum.

Generally speaking, the species of Palitdomns, Acrostoma and Indonaia are inhabitants of running water. Paludoinus is found as a rule in mountain streams or at any rate in running water near the base of hills and on a stony bottom, while Acrostoma and Indonaia need mud and therefore less rapid water. As is suggested in Dr. Baiui Prashad's part of this paper, the genus Lamellidens can probably be divided into two sections from an ecological point of view, one, which produces very large numbers of embryos and
as a rule frequents running water, the other, with a smaller number
of embryos, that affects ponds and swamps. These observations,
to which there are of course exceptions, are on the whole substan-
tiated in Manipur, but in applying them it must be remembered
that conditions in a very sluggish, weed-choked stream often
approximate closely to those in a swamp and attract paludine
forms.

Variation and Plasticity.

It is particularly interesting to contrast the Manipur Valley
with that of the Inle Lake in reference to the variability and plas-
ticity of the aquatic molluscs. As I have pointed out in the Intro-
duction to this paper, the two valleys have certain physical fea-

[Begin Page: Page 626]

626

Records of the Indian Museum. [Vol. XXII,

tures in common, others, which are perhaps more important,
widely divergent. Comparatively few species of molluscs are iden-
tical in the two localities, and the general facies and composition
of the fauna is very different. In the Inle Valley the two families
of molluscs most remarkable for their plasticity are the Vivipari-
da and the limnaeidae. As this is also so in the Manipur Valley,
it will greatly simplify my comparison if I confine my remarks to these two families. I will begin to do so by drawing up in tabular form the main differences between the Viviparidae of the Inle Lake and those of the Manipur Valley.

In considering the meaning of the differences thus summarised expressed we have to take into account not only the differences in environment but also the idiosyncracies of the different genera represented, for there is no fact more evident in the study of the freshwater molluscs than that different genera have different tendencies in the matter of variation and plasticity. At present we have three genera to consider, Vivipara, Lecythoconcha and Taia. It will be convenient to take Lecythoconcha first.

Although this genus is present in both valleys it is so scarce in the Inle Valley, and I know so little about it there, that I must confine my remarks, so far as my own observations go, to its peculiarities in Manipur. I have selected this genus as the protagonist in my argument because its case is not complicated by the production of an abnormal and exuberant shell-sculpture. We may indeed, so far as Manipur is concerned, regard Lecythoconcha as a smooth-shelled genus. Further east, especially in Japan, we find shells presumably of this genus with a type of sculpture very like that of Vivipara oxytropis, but we know nothing of their anatomy and they must for the present be ignored. It is probable that their case is similar to that of the species of Vivipara already mentioned and to be discussed further.

The one species of Lecythoconcha found in Manipur extends
the range of the genus a considerable distance westwards from its

[Begin Page: Page 627]

1 92 1.] Manipur Molluscs. 627

headquarters in China, but it has colonized the Manipur Valley
successfully and is at home in practically every part of its waters
except in streams and rivers. Its plasticity is remarkable, and
has probably aided it in taking possession of a very large territory.
In the Manipur Valley we found no less than four phases common,
each in its proper environment, and, so far as I know, only one of
these phases has been found outside the valley, unless the locality
" Sylhet " is correct for the forma typica, which I doubt greatly.
Should my doubt prove unfounded it will not alter ray argument.
Of the four phases the largest and best developed is the one found
in the central parts of the Loktak Lake, amidst dense submerged
vegetation but in comparatively clean water of relatively consi-
derable depth. The shell in this phase provides less evidence of
interrupted growth than any of the others, less individual varia-
tion and as a rule a greater symmetry in proportions. It is, indeed,
of just such a type as might be expected to occur in conditions in
every respect favourable to the species. The only approximation,
however, to a true lacustrine type exhibited b) it is its comparative
thinness. It has no tendency whatever to assume the elongate
conical outline of the lacustrine species of Taia. Indeed, it is
more globose than the shell of either the phase found at the edge
of the great swamp or that found in ponds. The rice-field phase, on the other hand, is still more globose than the deep-water one, but does not possess its symmetry or constancy to type.

It is evident that we are here dealing with plasticity of a somewhat different type from that illustrated by the genus Taia in the Shan States, and with one in which the direct result of environment on the individual may be more safely postulated.

Indirectly the structure and post-embryonic development of L. lecythis cast an interesting sidelight, though the adult shell is smooth or nearly so, on the question of the development of prominent spiral sculpture on the shells of the Viviparidae in certain circumstances, but this point can be discussed more clearly after the facts about Vivipara oxytropis have been summarized.

Of the three species of Vivipara found in Manipur two are very scarce and have not been seen by me in their natural surroundings. The third (F. oxytropis) is, however, abundant and shares with L. lecythis the position of a dominant species throughout the valley. Two points have to be considered in reference to this species, its plasticity and its peculiar sculpture, the latter not so much for its own sake as for the light it throws, taken with certain facts in the life-history of L. lecythis, on larger questions.

V. oxytropis is not quite so abundant or so universally distributed in the Manipur valley as L. lecythis. It is very nearly if not quite as common in the Loktak Lake, but much scarcer in most
ponds and practically absent from the smaller swamps. This may perhaps be correlated with two facts, firstly that it is not nearly so plastic (i.e., cannot adapt its external form to different types of environment so well), and secondly that it is so largely parasitized not only by a trematode (Lencochlaridiium encysted in its mantle,

[Begin Page: Page 629]

I921.] Manipur Molluscs. 629

The importance of V. oxytropis in the study of these phenomena only becomes apparent when we compare the structure of its mantle and shell with those of the mantle and shell of Taia and contrast the constant character of the Manipur species with the plasticity and variability of such a species as T. naiicoides. This I have done in another paper in the Records of the Indian Museum.

We may now turn to the Limnaeidae of the Inle and Lok-tak Lakes. In the former body of water three species have been found, namely Uninaea shanensis, Annandale, L. andersoniana, Nevill and L. mimeica, Annandale. The last is a small and highly peculiar species only known from the Inle Lake and not exhibiting noteworthy variability or plasticity, except in so far that it is probably as a species the product of plasticity in some form of the L. aciuuinata group. L. shanensis is not strictly speaking, a variable species, and we only know that it is or has been
highly plastic through the existence of fossil or subfossil phases.

With L. andersoniana I will deal presently.

In the Loktak Lake the only species of Limnaea collected was L. acuminata, but we may consider with it two other species found in swamps or ponds in the Manipur Valley. These are L. ovalior, sp. nov., and L. andersoniana, Nevill.

L. acuminata provides us with one of the best examples of true or individual variability to be found in the genus. In some districts (see fig. 12, p. 569) there is a very great difference in the shape of different shells from the same environment, but this is not so, apart from aberrations or monstrosities, in the Loktak Lake. A slight plasticity, however, is to be found in that individuals from the less congested parts of the swamp have a distinctly smaller shell and a shorter spire than those from the margin, while those from a small sluggish stream in the vicinity have remarkably pale and fragile shells with a strong but irregular external sculpture.

An interesting aberration is represented in our collection by a single specimen. It is remarkable for the very poor development of its spire, a feature common in lacustrine forms of the genus.

L. ovalior is known only from the swamps that surround the Loktak Lake and from Dimapur in the plains of Assam, north of the Naga Hills. In the latter locality it was found in a single pool of very foul water. Shells from this situation differ from
those from the Manipur swamps in the same way as, but to a
greater extent than, those of L. acuminata from the more con-
gested part of the Loktak Lake do from those of the same species
from its open region.

It is in L. andersoniana, however, that plasticity occurs in
the most highly developed state. In the Inle Valley two forms of

\ol. XXn. pp. 243-266 (1021;.

[Begin Page: Page 630]

630


[Vol. XXII,

this species have been found — a broad form in ponds and a narrow
form in a small stream. In the Manipur Valley and at Dimapur
no less than four such phases occur. Two of these are almost
identical with the two from the vShan States and inhabit similar
types of environment. A third phase, still narrower than that
found in rapid running water in the valley, inhabits higher parts
of the same streams, where they have the character of mountain
torrents. Perhaps, however, the most interesting phase is that
found at Dimapur in small cattle-ponds. It may be described as
both intermediate in some individuals between the pond phase and the ordinary stream phase, and also, in other individuals, as a more extreme form of the pond phase. A partial explanation is probably to be found in the fact that the ponds it frequents are connected in the rainy season with small streams. The narrower individuals may be those that have grown up in these temporary streams, while the broader individuals are those that have never left the ponds.

We thus see that whereas the type of plasticity characteristic of L. andersoniana is essentially similar in the Inle and Manipur Valleys, that observed in the Viviparidae is different in kind in the two localities. We do not find any species of mollusc in Manipur that exhibits the extreme variability in shell-sculpture of Taia naticoides, in the Shan States, and even in L. acuminata variability in shell-form is much less marked in the Loktak Lake than it is in many other localities. In the present state of our knowledge it is as well not to speculate further as to the meaning of these observations.

ADDENDUM.

Note on Sphaerium montanum Tapparone-Canefri.

Since this paper went to press I have, through the kind offices of Dr. R. Gestro of the Genova Museum, had an opportu-

1 EXT-FiG. 36. — Type-shell of Sphaerhtm Text-fig. 37.— Hinge ot the same.
montauum, Tapparone-Canefri.

The opportunity of examining the unique type-specimen of Tapparone-Canefri's Sphaerium montanum from Tenasserim, Burma, which I had been unable to include in my revision of the Indian species of the genus Sphaerini (supra, p. 614) owing to insufficient information.

As a result of my examination of the unique type I am now able to confirm the author's opinion of his species from Burma being a distinct species. In the Indian Museum I was also fortunate in finding a specimen in Theobald's Burmese collections of Unionidae which is referable to this species. Unfortunately the exact locality of Theobald's specimen is not known.

I have nothing to add to Tapparone-Canefri's description, but give below the measurements of the type-shell and of Theobald's specimen. I have also taken this opportunity to publish a figure of the shell and the hinge-teeth of the type-specimen.

Measurements (in millimetres).

<table>
<thead>
<tr>
<th>Type-specimen</th>
<th>Theobald's specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>8-2</td>
</tr>
</tbody>
</table>
Breadth . . . . 7-3 7-4

Thickness . . . . 4 3-9

Tapparone-Canefri compared his species with S. indicum. Deshayes, but was doubtful as to its possible identity with S. avanum, Theobald. The species, however, has no relationship with S. avanujii, and forms a distinct group with S. indicum and S. austeni. From either of these species it is easily distinguished by its subquadrate shape, less tumid shell, less prominent umbones, which do not project so far upwards and inwards as in the other two species, proportionately larger lateral teeth and in having the two lamellar cardinals of the right valve distinctly separated from each other by a fairly deep notch.

[B. Pr.shad.]

XXIX. INDIAN CYPRINOID FISHES BELONGING TO THE GENUS GARRA, WITH NOTES ON RELATED SPECIES FROM OTHER COUNTRIES.

By Sunder l^.

\h Hor., M.Sc, Assistant Superintendent,
Zoological Survey of India.

(Plates XXIV—XXVI).

Contents.

Introduction

History

Probable evolution of the disc of Garra. as represented by a specimens collected in Manipur, Assam

Skeleton of the mouth-parts

\(\text{ir-bladder and associated skeletal structures}\)

0'a,')-a and Discognathiis

Synopsis of the Indian and some Extra-Indian species of Garra

Part 1. Indian species of Garra

Part 2. On some Extra-Indian species of Ga7')-a

Bibliography

of

Page
INTRODUCTION.

Among the Indian fresh-water fishes few have greater interest in the study of evolution than those belonging to the genus Garra. Great confusion has prevailed in the taxonomy of this genus, partly because many of the species exhibit considerable individual variability, and partly because ichthyologists have attempted to apply to them specific standards unsuitable for forms apparently still in the process of adaptation to their environment. Scale-counts, number of fin-rays and proportions are all important diagnostic characters in most Cyprinid genera; but in Garra, at any rate, they have much less significance than the structure of certain organs and appliances modified or produced in correlation with the peculiar mode of life adopted, apparently not very long ago, by the members of the genus. Before expressing an opinion
as to how this has come about it is necessary that the genus
should be investigated as completely as possible ou anatomical
and taxonomic lines. This Annandale attempted to do, so far as
the taxonomy of the Indian species is concerned, in two recent
papers (1919a, b), while Narayan Rao (1920) has still inore recently
published a third paper on the same subject and Annandale and
I have discussed the generic position of the fish in a fourth
(1920).

[Begin Page: Page 634]

634 Records of the Indian Museum, [VoI., XXII.

The great difficulty under which we have laboured hitherto
has been that the type-specimens of older species were not
available and that the figures and descriptions previously pub-
lished were inadequate. This difficulty has now been overcome to
a great extent, firsth' because the old collection of the Indian
Museum, including types of the species described by Day, which
was sent to Dr. V. Pietschmann before the beginning of war, has
been returned to Calcutta, and secondly because I have been able
to visit and obtain specimens from the same localities in which
Hamilton Buchanan found his specimens of Cyprinus (Garra)
lamta, the genotj^pe of Garra. The collection of the Zoological
Survey of India has also been verj- largely augmented by the addi-
tion of specimens from many parts of the Indian Empire, and we
have in particular received from Mr. Nara3'an Rao and Mr. G. E.
Shaw, to whom our best thanks are due, valuable series from Coorg and the Darjiling Himalayas respectively. The Bombay Natural History Society has also lent us some interesting forms, and practically all the Indian districts whence specimens of the genus have been described are now well represented in our collection.

My sincere thanks are due to Dr. N. Annandale for placing the valuable material in my hands for investigation and description and for allowing me to visit some hill-streams to study these fishes in nature. I am indebted to Dr. S. W. Kemp for going through the manuscript with me and also for some valuable suggestions. I have also to express my obligations to Mr. Tate Regan for the courtesy he has shown me in sending at my request a copy of Heckel's original description of the genus Discognathus.

HISTORY.

Hamilton Buchanan, in his classical work entitled "An account of the Fishes of the Ganges," published in 1822, was the first to describe a species — Cyprinus lamta — with a disc behind the lower jaw, which he "found in rivulets, with rocky bottoms, in the province of Behar, and in the Rapti River of the Gorakhpur District." This characteristic form be referred to his ninth division of Cyprinus which he termed Garra. A decade after this Gray (1832) figured a similar species, Cyprinus gotyla, also with a disc on the lower jaw, from "Mountain Stream, India"; while McClelland (1838, 1839, 1842) recorded a number of species with the same character from streams in the Eastern Himalayas. The latter, however, described his specimens under two genera, Goiio-
rhynclius and Platycara, and seems to have attached no importance to the character of the disc. Sykes (1841) also paid little attention to this well-marked structure in Chondrostoma mulya from South India and it was left to Heckel to recognise its value as a generic distinction when he referred his Syrian specimens (1843) to the new genus Discognatlius. Heckel refers to Gray's species and also to those described by McClelland, but seems to have been unaware of the existence of Cyprinus lamta and C Itondrostoma