

AQUATIC PULMONATA.

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The three families and most of the genera of this order that occur in the Oriental Region are well represented in the collection, namely the Limnaeidae, the Planorbidae and the Ancyliidae, the first by four species of *Limnaea*; the second by the unique species of *Indoplanorbis* and by species of *Gyraulus*, *Segmentina*, *Hippeutis* (?) and the highly peculiar genus *Camptoceras*; the third by three species of the subgenus *Ferrissia* of *Ancylus*.

This collection has enabled us to discuss plasticity and variability in the Limnaeidae, to give particulars about the anatomy of the different genera of Planorbidae and to revise the Indian species of Ancyliidae. Perhaps the most interesting points that have become manifest in our investigation are (1) the differences in environmental plasticity and individual variability shown by different species of *Limnaea*; (2) the homogeneity of the anatomy of the Indian species of the genus, contrasting with (3) the great diversity of structure in the soft parts of the Planorbidae; (4) the generic status of the common Indian "*Planorbis*' *exustus* and of the scarce *Camptoceras lineatum*; and (5) the precise systematic position of the Indian Ancyliidae.

Family LIMNAEIDAE.

Genus *Limnaea*, Lamarck.

Of the four species of the genus found in Manipur two are widely distributed in India (*L. acuminata* and *L. ovalis*), the range of one (*L. andersoniana*) extends from south-western China to Kashgar and Nepal, while the third, here described as new under the name *L. ovalior*, has been found outside the Manipur Valley only at Dimapur in the plains of Assam on the north side of the Naga Hills.

Small as is the number of species, they include so large a proportion of the true Indian *Limnaeae* that it will be worth while to discuss here as briefly as possible the species that occur in India proper, Assam and Burma, omitting those found only in the Himalayas or in the districts west of the Indus. A key to the species to be considered will form a suitable basis for discussion.

Key to the species of Limnaea found in the Indo-Gangetic Plain, Peninsular India, Assam and Burma.

- I. Spire of shell narrow and tightly coiled, with the suture very oblique and the upper extremity of the body-whorl not or hardly broader than the penultimate whorl.
 - A. Apex sharply pointed; shell usually large or of moderate size, with at least 5 whorls; columellar fold coarse and strongly twisted ... *L. acuminata*.
 - B. Apex minutely rounded; shell small or minute; columellar fold much less strongly developed.
 - i. Shell less than 8 mm. high, very fragile, with only two whorls in the spire, which is very short; columellar fold narrow and not at all twisted... *L. mimetica*.

- ii. Shell as a rule more than 8 mm. high, not so fragile with the spire normal and consisting of at least three whorls; columellar fold twisted *L. shanensis*.
- II. Whorls of spire transverse and increasing rapidly in size; suture not markedly oblique; at least four whorls in spire; columellar callus very coarse and broad; columellar fold coarse.
- A. Apical whorls of spire much narrower than others, forming a distinct apical process; penultimate whorl of shell much narrower than upper part of body-whorl, broader than height of spire ... *L. ovalis*.
- B. Whorls of spire increasing in size evenly; penultimate whorl at least nearly as broad as upper extremity of body-whorl.
- i. Shell almost symmetrical bilaterally and its outline forming a remarkably even broad ovate figure, with the base of the spire more than twice as broad as its height; umbilicus imperforate ... *L. ovalior*.
- ii. Shell of elongate ovate form, with the spire relatively long and narrow and the body-whorl sub-cylindrical; umbilicus imperforate ... *L. luteola*.
- iii. Shell varying greatly in outline but always opaque, with the suture much more impressed and more oblique than in the last two species; the umbilicus, though always completely occluded by the columellar callus, usually forming a narrow aperture visible on the dorsal surface ... *L. andersoniana*.

There is no genus amongst the Indian molluscs more liable both to individual variability and to plasticity in response to environment than *Limnaea*. The two phenomena are not always correlated in the same species and both differ greatly in degree in different species. Probably neither is ever completely suppressed. These facts make it difficult to assign specific limits to the numerous forms, and at the same time render it probable that the number of true species is small.

Various attempts have been made to solve the taxonomic difficulties involved in the study of the Indian Limnaeidae. The most successful in practice was that of the late Mr. G. Nevill,¹ but unfortunately he gave no arguments for adopting the course he followed. Von Martens² has discussed certain species in detail and has given admirable figures, but he had not seen by any means all the Indian forms. We have now been able to study *Limnaea* in relation to its environment in many parts of Peninsular India and the Indo-Gangetic Plain, on the North West Frontiers and at several places in Assam and Burma, and we believe that we have seen specimens of almost all the Indian forms to which specific names have been given and, with the exception of the Eurasian species of the Western Himalayas, have examined the natural surroundings of the great majority. This has given us confidence to discuss the species on broad lines, both from a geographical and a purely taxonomic point of view.

¹ *Hand List Moll. Ind. Mus.* I, pp. 232-234 (1878).

² *Conch. Mitth.* I, pp. 75-80, pls. xiv, xv (1881).

From a geographical point of view the Indian species fall naturally into four groups, which may be defined as follows:—

1. THE EURASIAN GROUP.—A small group of species found in the higher valleys of the Indus system in the Western Himalayas and consisting of species identical or almost identical with those of Europe.

2. THE AFGHAN GROUP.—Another small group, consisting of species that bear considerable resemblance to the *L. lagotis* and *L. peregra* groups of the Palaearctic Region. The range of this group extends from Afghanistan through the mountains west of the Indus in Indian territory and thence across the Perso-Afghan desert to Eastern Persia.

3. THE INDIAN PENINSULAR GROUP.—A group of three species with numerous phases, varieties and mutations. It occupies the whole of Peninsular India and the Indo-Gangetic Plain, and ranges eastwards to Burma and northwards into the Lower Himalayas east of the Indus.

4. THE BURMESE GROUP.—We know comparatively little about this group, which is probably of Chinese origin in the main. Its range probably extends from Upper Burma into Eastern Assam, but it occupies much territory in common with the Indian Peninsular group.

We are at present concerned with species in groups 3 and 4. The Afghan forms have recently been discussed by us in another volume¹ of the *Records* and the Eurasian forms have still to be compared in detail with their European representatives. Neither of these groups is found in any part of Assam.

We have stated our opinion that the Indian group consists of only three species, thus agreeing with Nevill (*loc. cit.*), but a large number of races, phases, varieties and aberrations have received specific names. The three species are *L. acuminata*, Lamarck, *L. ovalis*, Gray and *L. luteola*, Lamarck. The last has been called *L. succinea*, Deshayes, by some authors. We have to discuss here only *L. acuminata* and *L. ovalis*.

The Burmese group also comprises, so far as we are aware, only three species, viz. *L. andersoniana*, Nevill, *L. shanensis*, Annandale and *L. mimetica*, Annandale. The last is probably derived from the Indian *L. acuminata*, but the other two are probably of Chinese origin. We have here to discuss *L. andersoniana* and describe a highly peculiar new species from Assam, probably related to *L. ovalis*. The name we propose for it is *L. ovalior*.

Before discussing individual species in detail it will be as well to say something of the principles on which we have based their classification. We had hoped to find some diagnostic features in their anatomy and have examined the radulae and other internal organs of most of the Indian forms with this object in view; but we have been disappointed and are forced to the conclusion that shell-characters, provided that a sufficiently large number of indi-

¹ *Rec. Ind. Mus.* XVIII, pp. 39–52, pls. v–vii (1919).

viduals be examined, and due attention paid to the protoconch, form the most satisfactory basis for specific identification among the Indian species, among which conspicuous anatomical differences such as Baker¹ discovered in the North American Limnaeidae do not exist. Anatomical differences of course there are, but they are so minute, so difficult to find and above all so inconstant that they are of little use in taxonomy.

The radular teeth in all the Indian, Persian and Mesopotamian species we have examined conform to a type somewhat different from that described for any European species, differing in detail in the different forms, but vary greatly not only in accord with race and locality but also with individual idiosyncrasy, while small specific differences in the genitalia are liable to be obscured by the state of sexual activity, especially by protandry.

In the anatomy of the radula and genitalia the Indian Limnaeidae (omitting the Palaearctic Himalayan species) differ little from those referred by Baker to the Holarctic genus or subgenus *Galba*, Schrank, but the shell does not quite conform to this type. It is, indeed, of more than one type and *Limnaea acuminata* stands out very distinct in shell-characters from its congeners, and is more like *Galba* than the other species in our fauna.

Limnaea acuminata, Lamarck.

(Plate VII, figs. 1—3.)

1878. *Limnaeus acuminatus*, Nevill, *Hand List Moll. Ind. Mus.*, p. 233.
 1881. *Limnaea acuminata*, von Martens, *Conch. Mitth.* I, p. 75, pl. xiv.
 1915. *Limnaea acuminata* (in part), Preston, *Faun. Brit. Ind. Freshw.-Moll.*, p. 106.
 1919. *Limnaea acuminata* (with var. *nana*), *L. amygdalum* and (?) *L. chlamys*, Annandale and Prashad, *Rec. Ind. Mus.* XVI, pp. 140—142, figs. 3, 4, pl. iv, fig. 1, pl. v, figs. 1—3.

Preston, in the *Fauna of British India* has distributed the forms of *Limnaea* indiscriminately into subgenera and species and several of those he attributes to *L. acuminata* have, as von Martens had shown previously, no resemblance to it. We include in it here all the forms comprised in the species by Nevill and by von Martens, with the possible exception of *L. chlamys*, Benson. Of all the Indian freshwater Gastropods *L. acuminata* is the most liable to individual variability and it also exhibits considerable plasticity in response to environment. It is not surprising, therefore, that numerous names have been given to different "forms." Several of these (*patula*, Troschel, *rufescens*, Gray, *strigata*, Hanley and Theobald, *gracilior*, v. Martens) refer merely to shapes of shell that may be assumed almost anywhere in the normal environment of the species, i.e. in a pool of perennial water provided with abundant aquatic vegetation of a succulent nature

¹ *Spec. Pub. Chicago. Acad. Sci.* III (1911).

and situated in a tropical climate. In many spots, however, one or other of these forms may predominate and in some one or other may be absent. For example the form *gracilior* is far the commonest, though by no means the only one in the pond in the

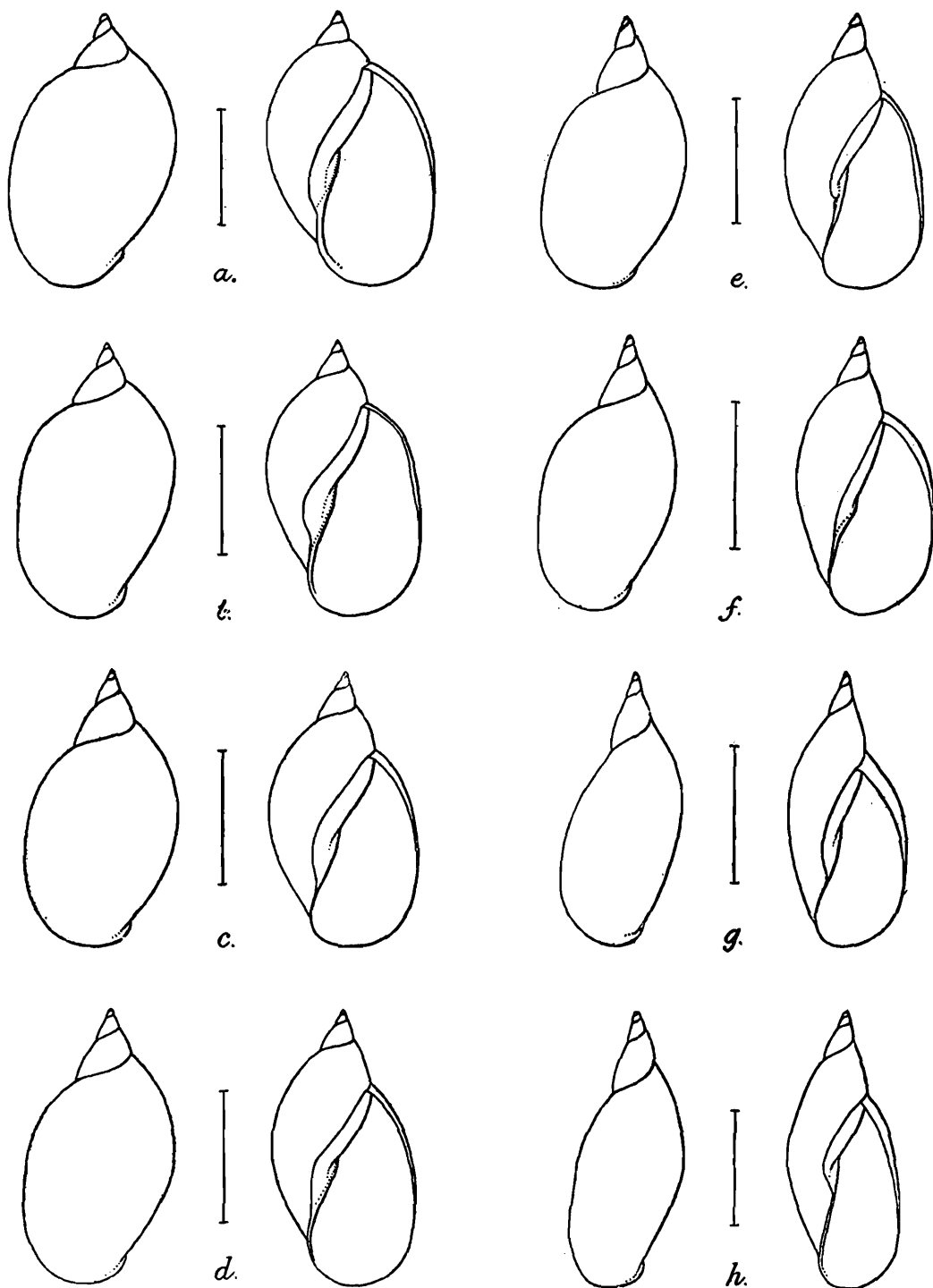


FIG. 12.—Series of shells of *Limnaea acuminata* from Manbhum, Bengal.

FIG. *a* may be taken to represent var. *patula*, Troschel and figs. *g* and *h* the var. *gracilior*, von Martens.

Museum compound, Calcutta, while no shell narrower than that of the form *rufescens* was found at any place in Manipur.

Other names again belong to phases associated with abnormal types of environment. The phase *nana*, Annandale and

Prashad, for instance, was described from a small ditch, liable to desiccation, in the Western Ghats and has since been found in a shallow pond at Rangoon. The phase *hians*, Sowerby, originally described from "Malabar," occurs, without much individual variation, in a swampy artificial lake situated at an altitude of 7,000 ft. in the Nilgiri Hills. A somewhat similar but more delicate phase, *ventricularis*, Küster, has been found in the Lake Nainital (altitude 6,400 ft.) in the Western Himalayas, and these two forms may probably be regarded as dwarfed mountain phases.

Differences in shell colour are probably correlated in most cases with differences in the water in which the specimens are found.

We are in some doubt about Benson's *L. chlamys*, which differs from all other forms of *L. acuminata* with which we are acquainted in the brilliant golden colour of its shell, the relative width of the body-whorl and its strong spiral sculpture. On the only occasion on which either of us has found *L. chlamys* it was discovered living in abundance on rocks covered with algae in an artificial reservoir in the hill-fort of Satara—a type of environment very unusual for *L. acuminata*. The specimens were small and rather narrow but exhibited the diagnostic characters clearly.

L. acuminata is common in the Manipur Valley, in which, however, we obtained no specimens of the extreme narrow type (*gracilior*, von Martens). Indeed the shells obtained showed less individual variability than in many districts and were for the most part of a type approaching the mean in shell form, neither very narrow nor particularly broad. No very large specimens were seen, and none that could be called dwarfed. The average size of shells was, however, distinctly smaller than usual. One or two points of interest may be further noted in detail as regards plasticity and aberration.

Our collection is from different parts of the Loktak Lake, from ponds, swamps and small bathing-pools and from a stream. The specimens from the Loktak Lake provide evidence of distinct but not extreme plasticity. If shells from clean beds of *Potamogeton* in the lake (pl. VII, fig. 2) be compared with those from its rather foul and swampy margin (pl. VII, fig. 1), the following differences are apparent:—(1) the shells from the open lake are in most instances distinctly smaller and have a shorter spire (see table of measurements) than those from the margin. In both series the colour is a deep chestnut brown, but those from the margin are coated externally with a black deposit. The shell in the latter is also a little thicker and the sculpture coarser and more regular.

The most characteristic series in our collection, however, consists of specimens from running water. These were found on floating grass-stems and among green filamentous algae in the small stream that runs past Potsengbam into the north end of the Loktak Lake. They occurred only at places at which the water was clean and deep and flowed fairly rapidly. The shells in this series are almost colourless and so thin and brittle that we found it difficult to secure perfect specimens. Their surface is deeply

but irregularly sculptured and may be described as coarsely malleated. The shells are narrow, with long spires but not of extreme type in shell-form. They are rather small. The animals in these shells were very pale in colour.

Two abnormal specimens may now be described. They were found together in a bed of *Potamogeton* at the point at which the main outflow leaves the Loktak Lake. One only differed externally from the majority found with it in its larger size. It is numbered A (1) in the table of measurements. We may note that its size was large only in comparison to other individuals found with it, for much larger individuals are common at some places. On dissection it was found that the body-cavity of this individual was occupied by a contorted mass of elongate filiform Trematode sporocysts, which completely surrounded the upper part of the genital system. All the genital glands were crowded together in a degenerate mass, while the female ducts could not be traced. The lower part of the vas deferens and muscular penis-sac with its retractor muscles were, however, intact.

The other abnormal specimen (pl VII, fig. 3) was peculiar in shell-form. It was remarkable for the very small size of its spire and the relatively great length of the aperture of the shell. The interesting feature of this abnormality (or? mutation) is that the peculiarities in shell-form are among those commonly found in lacustrine species and phases of the genus. The shell, however, had not all the characteristics of such forms as it was no paler, thinner or smaller than those taken with it.

Measurements of Shells (in millimetres).

	A		B		C		D		E		F	
	1	2	1	2	1	2	1	2	1	2	1	2
Length ...	34.2	16.4	22	18.9	27.2	24.4	25.9	22.1	21	21.5	12.4	13.1
Breadth ...	19.3	9.7	13.9	11.4	16.3	14.5	15.7	12.6	11.9	13.3	6.9	7.8
Length of aperture ...	27.8	15	18.4	15.3	21.2	19.6	20.6	17.1	16.3	17.2	9.6	10.9
Breadth of aperture ...	15.1	8.2	11.5	9.4	12.8	12.1	14.2	9.8	1.4	10.3	5.8	6.5
Length of spire (dorsal view).	5.3	1.4	3.4	3.1	5.4	3.7	4.6	5	3.9	3.6	2.5	2.2
Breadth of spire (dorsal view).	8	2.7	4.3	4.2	6.5	5.6	6.1	5.4	4.7	4.5	3.1	2.8

- A. A small channel south of Thanga Island with bed of clean *Potamogeton* abnormal specimens; (1) is the large specimen and (2) the short-spined form.
- B. Same locality (normal individual).
- C. Swamp at Thanga Island in the Loktak Lake.
- D. Small muddy bathing pools Thanga Island.
- E. Potsengbam, northern end of the lake.
- F. Amingaon, near Gauhati, Assam.

Limnaea ovalis, Gray.1878. *Limnaeus ovalis*, Nevill, *op. cit.*, p. 233.1881. *Limnaea ovalis*, von Martens, *op. cit.*, p. 81, pl. xv, figs. 1-4, 8, 9.

This species is much less variable but more sporadic in occurrence than *L. acuminata*. One adult and two young specimens were found at Chigi Turel on the Chugnu Road in Manipur by Mr. Sunder Lal Hora in a small shallow channel of water. The adult specimen is not quite typical but may be described as intermediate between those figured as var. *prunum* and var. *nucleus* by von Martens in the paper cited. It is, however, smaller than either, its height being 19.5 mm. and its maximum diameter 12.1 mm. It is of a dull opaque purplish brown colour and rather thick.

L. ovalis has been found at various localities in the Ganges Valley and also at Golconda in Hyderabad (*Annandale* and *Kemp*). It is often abundant where it occurs. It has been recorded, doubtfully, from Assam and with less doubt from the lake country of Kumaon in the Western Himalayas, but not from Burma.

Limnaea ovalior, sp. nov.

(Pl. VII, figs. 4—6.)

The shell is of moderate size and thickness, of a very regular and symmetrical oval shape, of a bright chestnut brown colour and unusually opaque when quite fresh and clean. It is about $1\frac{1}{2}$ times as high as broad. The spire is short and blunt, consisting of $3\frac{1}{2}$ or 4 whorls and never occupying more than about $\frac{1}{4}$ of its total height. The spiral of the first $2\frac{1}{3}$ or 3 whorls is transverse, but above the basal whorl of the spire it becomes oblique and above the body-whorl still more so. The suture is impressed round the terminal whorls of the spire, but much less so above the two last whorls of the shell and the upper part of the whorls is not at all shouldered or angulate. The whorls increase in breadth rapidly and the basal whorl of the spire is nearly as broad as the upper part of the body-whorl. The latter is very regular in outline and dorsally is about $1\frac{1}{3}$ times as long as broad, its anterior extremity is evenly rounded and very little expanded. The aperture is long and rather narrow, extending for about $\frac{7}{10}$ the height of the shell; it has an auriculate outline, is sharply pointed above and very little oblique. The outer lip is sharp and evenly arched. The umbilicus is completely occluded by the columellar callus, which is broad, coarse and high, extending to the outer lip above and at its outer extremity covered over by it. The columella is short and twisted and nearly straight as a whole. The sculpture consists of fairly regular fine, slightly curved longitudinal ridges, some of which, probably representing the growth-periods, are coarser than others. They are barely visible to the naked eye. The profile of the external surface is moderate.

Shells from Dimapur, Assam, are a little smaller, narrower and less symmetrical than those from Manipur.

Measurements of Shells (in millimetres).

	A	B	C
Length	17·4	15·2	16·1
Breadth	11·5	10	10·8
Length of aperture	12·3	11·1	11·6
Breadth of aperture	7·4	7·2	7·4
Length of spire (dorsal view)	4·2	2·6	3·3
Breadth of spire (dorsal view)	6·5	5·1	6·4

All the above specimens are from a swamp at Thanga Island in the Loktak Lake.

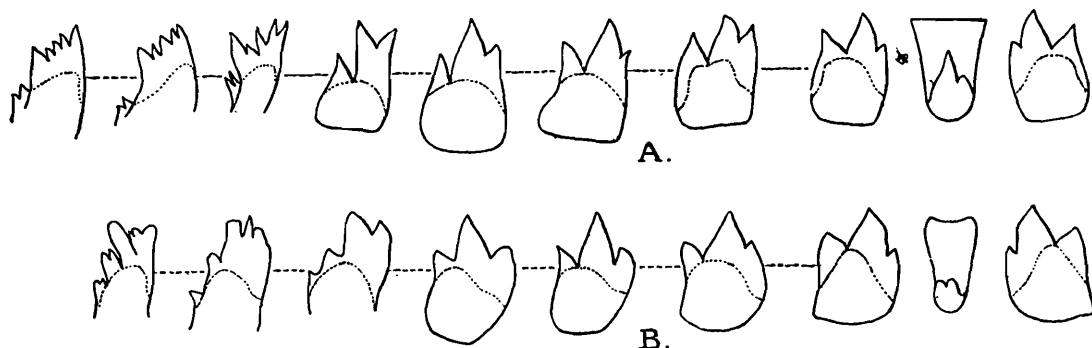


FIG. 13.—Radular teeth of *Limnaea*.

A. *L. ovalior*, Annandale and Prashad.

B. *L. andersoniana*, Nevill.

The animal is of unusually dark colour with the mantle black, unspotted or with faint and relatively small round spots, and with pale margin. As in all Indian species examined by us, the tentacles seem to be shorter than those of some European forms. The cephalic lobes are large and broad and the foot is comparatively small, bluntly pointed behind and somewhat expanded at the antero-lateral angles. The eyes are small.

The mouth is small and the upper jaw stout, semicircular and black. The lateral pieces are slender but well cornified and dark in colour. The radula is short and broad, narrowing abruptly in front and rounded at the tip. The whole buccal mass is relatively small. The dental formula is approximately 19.12.1.12.19. The lateral and marginal teeth are well differentiated and the latter have a deep yellowish tinge. The cusp of the central is stout and relatively large, with a distinct lobe on the right side. The laterals are distinctly tricuspid, but the entocone is much shorter than the other cusps and is apt to be concealed by being turned in under the mesocone. The mesocone and ectocone are long and sharp. The laterals are unusually stout. They are multicuspid

with the outer and inner cusps larger than the others. Their bodies are long, narrow and oblique.

The oesophagus is long and narrow, the gizzard large and powerfully developed, occupying the greater part of the stomach. The genitalia do not differ materially from those of other Indian species. The penis-sheath is large and sausage-shaped, pigmented and of a greyish colour. The spermatheca, which is full of spermatozoa in specimens examined, is pyriform and possesses a duct about half as long as itself.

Type-specimens.—M 11717/2, Zool. Surv. Ind. (*Ind. Mus.*).

Locality, etc.—This species was found in fair abundance in a drying peat-swamp on the east side of the Loktak Lake, Manipur, in February, 1920. It leads an almost amphibious existence in and on the damp mud at the edge of buffalo-wallows and other small pools. There is no true aquatic vegetation in its haunts and it appears to feed on mud and decaying vegetable matter. A specimen was found to be heavily parasitized with sporocysts and cercariae, but unfortunately all those brought living to Calcutta for examination died on the way. Specimens were also obtained in a pool of very foul water in the jungle near Dimapur, Assam.

There can be little doubt about the affinities of *L. ovalior*, which is evidently no more than a final link in the chain of evolution of which *L. andersoniana* with its diverse phases is the predominant component. We will discuss this point further when dealing with that species.

Limnaea andersoniana, Nevill.

(Pl. VIII, figs. 1—6.)

1908. *Limnaea (Gulnaria) simulans*, Preston, *Rec. Ind. Mus.* II, p. 49, fig. 6.
 1918. *Limnaea andersoniana*, Annandale, *Rec. Ind. Mus.* XIV pp. 106, 149, figs. 4a, 4b.

In his original description of *L. andersoniana*, as one of us has pointed out in the paper cited, Nevill included, in addition to the central Asiatic form he later recognized as distinct, two that at first sight appear rather different. The view that these represent respectively a pond and a stream phase of a single species is fully borne out by recent observations in Manipur and eastern Assam, in which *L. andersoniana* is abundant. Further particulars may, therefore, now be given.

The *forma typica* of the species, as represented by Nevill's type-specimen (pl. VIII, fig. 1) from Nantin in Yunnan, has a small, rather fragile shell of a pale brownish colour and an ovoid form. The spire is acuminate and exerted, but by no means long. There are $4\frac{1}{2}$ whorls and the spiral is moderately oblique. The suture is impressed and the upper extremity of each whorl is narrowly flattened outside it. The lowest whorl of the spire is much narrower than the body-whorl and is situated on its inner

side. The body-whorl is relatively long and somewhat oblique, about $1\frac{1}{2}$ times as high as broad; its inner outline is distinctly sinuate and its anterior extremity is somewhat narrowly rounded and a little expanded. The channel leading to the umbilicus can be seen from the dorsal view. The ventral surface and the aperture are in every respect very like those of *L. ovalis* and *L. ovalior*, except that they are narrower. The sculpture is very like that of *L. ovalior*, but a little more regular. The height of the type-specimen is 10 mm., the minimum diameter 6.4, the height of the spire 2.5, that of the mouth 7.3 and the maximum diameter of the mouth 4.5 mm.

This description would apply equally well to shells from ponds at Imphal in Manipur, except that they are a little larger and the body-whorl is a little broader. Shells from ponds in the Yawngwe Valley in the Southern Shan States resemble the type-specimen even more closely. Shells from a pond at Dimapur in the plains of Assam immediately north of the Naga Hills show greater individual variation. In some the difference consists merely in an almost imperceptible reclination of the expansion of the anterior margin and a slight broadening of the penultimate whorl. In others, however, which are invariably larger, the spire is decidedly shorter and broader and the body-whorl broader and more oblique. These shells form a connecting link between *L. andersoniana* and *L. ovalior*. We will discuss the conditions in which they were living shortly.

The great majority of Nevill's specimens from Yunnan (including shells from the same locality as the type-specimen) and also one examined by him (and a number examined by us) from the Southern Shan States, represent the other phase hitherto unrecognized, differing in their smaller size, longer and narrower spire, narrower aperture and body-whorl. In other words their spiral is more tightly coiled and they are reduced in size. Specimens from a small muddy stream in the Yawngwe Valley closely resemble these shells.

Shells from a hill-stream with clear water running rapidly over a stony bed near Bishenpur on the west side of the Manipur Valley represent yet a fourth phase. They are still narrower than those from the Yawngwe stream, of more fragile structure and of a rich golden brown colour. Some of them are also considerably larger. Shells, however, from the same and adjacent streams a little lower down, after they have reached the valley, and from rice-fields irrigated from those streams, agree precisely with the Yawngwe phase.

There can, therefore, no longer be any doubt that *L. andersoniana* is a polymorphic species and that its various forms are correlated with different types of habitat. It is possible to recognize four phases, for which it will be convenient to have names, though there is no reason why these names should not be English. We will give a synopsis of the phases and the circumstances in which they have been found.

Phase I (INTERMEDIATE) (pl. VIII, figs. 2-5).—This phase was found in a fairly large swampy pond, evidently connected with a small stream in the rainy season, at Dimapur and in several ponds at Imphal, Manipur, in February and March, 1920. The ponds were well supplied with submerged aquatic vegetation but the molluscs were most abundant (at Dimapur) in a half isolated pool with no vegetation of the kind and evidently forming part of the bed of a sluggish stream for part of the year. They were pairing and ovipositing in March, i.e. some months before it is probable that the stream would be running. In these conditions greater individual variability occurred than among individuals living (at Imphal) amongst dense vegetation in permanent ponds. Imphal (2,600 ft.) is probably situated at a somewhat higher altitude than Dimapur.

This phase, as we have pointed out above, is a connecting link between *L. ovalior* and *L. andersoniana*. Many individuals of it come rather close to the former species, but all are much smaller, have the body-whorl less inflated and the penultimate whorl rather broader. The sculpture is also less coarse and more regular. The shell is usually broader than in the next phase and capable of growing larger.

PHASE II (POND PHASE) (pl. VIII, fig. 1).—This is the *forma typica* of the species and has been found both in Yunnan (in unknown circumstances) and also in ponds full of submerged vegetation in the Southern Shan States, at altitudes of 3,000 feet or over. The shell is narrower and as a rule more fragile than in the former phase. Similar but slightly broader specimens occur in pools at Imphal.

PHASE III (STREAM PHASE).—Specimens have been found in muddy spots at the edge of streams in the Southern Shan States and in the Manipur Valley, also in rice-fields irrigated from the same streams; and in unknown circumstances in Yunnan, Kashgar and Nepal at altitudes between 2,600 and 5,000 feet. They occur, often in large numbers on bare mud in an entire absence of phanerogamic vegetation. The shell is considerably narrower and usually smaller than in the preceding phases, rather thicker and duller in colour. This phase has been described by Preston under the name *Limnaea simulans*.

PHASE IV (HILL-STREAM PHASE (pl. VIII, fig. 6).—Specimens of this extreme phase were collected in a hill-stream near Potsengbam on the west side of the Manipur Valley. The stream has a rapid current, very clear water and a bottom of small pebbles and stones. The specimens of *Limnaea* were found attached to the pebbles in a shady area along the banks. The shell of these specimens is still narrower and more elongate than in the preceding phase, with the spire smaller and less regular, and the callus less indistinctly marked; the mouth is narrower and more pointed. The shell itself is paler and more polished.

Measurements of Shells (in millimetres).

	Intermediate Phase.		Stream Phase.		Hill-stream Phase.
	1	2	1	2	
	Length	15·6	12·9	11	
Breadth	10·7	8	6·2	5·6	6
Length of aperture	11·3	8·4	6·4	6·1	7·1
Breadth of aperture	6·7	4·7	4·9	3·4	3·7
Length of spire (dorsal view)	3·8	3·6	3·6	3·3	3·4
Breadth of spire (dorsal view)	5·6	4·4	3·4	3·1	3·6

We figure the radula (fig. 13, B) of a specimen of the intermediate phase from Dimapur, Assam.

Family PLANORBIDÆ.

As the Manipur Valley is rich in species of this family, and as representatives of all the main Indian types occur in it, we have taken the opportunity to carry out, so far as our present knowledge permits, a generic revision of the Indian species.

This revision has had interesting results from a morphological point of view, for it shows that branchial structure and shell-form are not necessarily correlated. In our new genus *Indoplanorbis*, which has a typical discoidal shell, the branchial process is folded, while both in the other Indian genera with shells of the same type and in *Camptoceras*, the shell of which is more or less *Physa*-like, the process is simple as in *Planorbis*, s.s. The contribution we are now able to make to the anatomy of Benson's peculiar genus leaves no doubt that Walker¹ was right in assigning it to the Planorbidae and that its resemblances to the Ancyliidae, on which we previously² laid stress, are hardly more than superficial.

I. Shell flat and discoidal (Planorbiinae). Anal siphon incomplete.

A. Shell relatively large and thick with the whorls convex above and below, both animal and shell clearly sinistral. Penis without a horny stylet.

i. Young shell not as a rule *Physa*-like, animal with a simple branchial process. Radula long and narrow, the cusps of the teeth thin and set on a lower level than their bases. Penis short and swollen when retracted, asymmetrical; penis sheath, with a thick-walled preputium, two retractor muscles present

ii. Young shell *Physa*-like. Branchial process lobed. Radula relatively large and broad, with the tips of the cusps of the teeth no thinner than the

Planorbis.

¹ *Occ. pap. Mus. Zool. Univ. Michigan*, No. 64 (1919).

² *Journ. As. Soc. Bengal* XIV, p. 457 (1919).

- bases. Penis long, a simple cylindrical tube; penis-sheath similar, no retractor muscle ... *Indoplanorbis*.
- B. Shell thin, as a rule small, if more than 1 cm. in maximum diameter with the whorls flattened below. Branchial process simple.
- i. Shell always less than 1 cm. in diameter, apparently dextral (though the animal is sinistral), with the whorls convex above and below but flattened as a whole, usually with a peripheral keel. Radula like that of *Planorbis*. Penis relatively long, provided with a horny stylet; preputium of complicated structure; a single retractor muscle present ... *Gyraulus*.
- ii. Shell small or of moderate size, flattened below, without internal teeth or folds. Radula extremely small with minute teeth; laterals twinned. Penis relatively short and stout without a horny stylet ... *Hippeutis?*
- iii. Shell small, resembling that of last genus but usually with hard enamel-like vertical ridges. Radula as in *Gyraulus* but with the lateral and marginals more numerous. Penis long and narrow, asymmetrical with horny stylet; penis-sheath with a pair of lateral lobes at its upper extremity; preputium well developed with a single retractor muscle... *Segmentina*.
- II. Shell ovate or almost cylindrical, sinistral (Bullininae). Shell small and thin, elongate, with the suture remarkably broad, deep and oblique. Animal with a simple branchial process, and a well developed left epipodial leaf-like lobe, which can be spirally coiled to form a complete anal funnel. Radula like that of *Gyraulus* but with broader denticulations on the teeth. Penis broad and stout, without a stylet ... *Camptoceras*.

Indoplanorbis, gen. nov

1915. *Planorbis*, Preston, *Fauna. Brit. Ind. Freshw.-Moll.*, p. 115.

The adult shell is relatively large and thick and closely resembles that of *Planorbis* (s.s). The whole is discoidal, but the whorls are convex and the suture deeply impressed. The aperture is ear-shaped, with the broader end (morphologically the lower extremity) uppermost when the shell is held with the mouth on the left. The young shell resembles that of *Physa* and is ovate, with the upper extremity flattened and the lower somewhat pointed, the spire being nearly flat.

The animal is sinistral. Its foot is relatively broad and short, leaf-shaped, broadly rounded in front and pointed behind. The head is very broad and has its lower margin expanded and flattened. The tentacles are elongate and filiform. The eyes lie at the inner base of the tentacles and are completely sessile. The mouth opens on the lower surface of the head in front of the foot.

The jaw is narrow and has lateral pieces of the usual type. The radula is broad having more than 20 longitudinal rows of marginals. The central is relatively large and bicuspid. The laterals are tricuspid, short and broad; the free lobe equals the base in length. They closely resemble those of *Limnaea*. The transition between the tricuspid laterals and the pectinate margin-

als is gradual. The denticulations of the teeth are not separated by any sharp line of division from the free lobe, but the whole structure is continuous as in *Limnaea*.

The genital aperture, which is situated some distance behind the left tentacle, is slit-like and relatively large. The vas deferens opens directly without invagination into an elongate cylindrical eversible penis with a bulky lumen. This organ is slender, tubular and of considerable length, extending practically to the end of the penis-sheath when contracted. Its orifice is circular and symmetrical. It is similar in form to the penis-sheath, which is a long, somewhat curved, thin-walled tube. There is no retractor muscle. The whole apparatus is, therefore, much less complicated than any of the types recognized by Simroth. There is no penial stylet. The female genitalia are of the usual type.

Type-species. — *Planorbis exustus*, Deshayes.

This genus differs from the true *Planorbis* of Müller (with the European *P. cornuus*, Linn., as type-species)

in the structure of the branchial process, the radula and the genitalia. The shell also has a characteristic facies, although it is difficult to formulate the differences precisely. The shape of the aperture is noteworthy. The branchial process apparently resembles that of *Bullinus*¹ and *Miratesta*,² while the radular teeth are not unlike those of the subgenus *Galba*³ of the genus *Limnaea*.

As Mons. L. Germain shows in his catalogue of the Planorbidae in the collection of the Indian Museum (now in the press) all of the larger discoidal shells of the family from the Indian Empire that are preserved in the collection belong to *Planorbis exustus*, Desh., the type-species of our new genus. A consider-

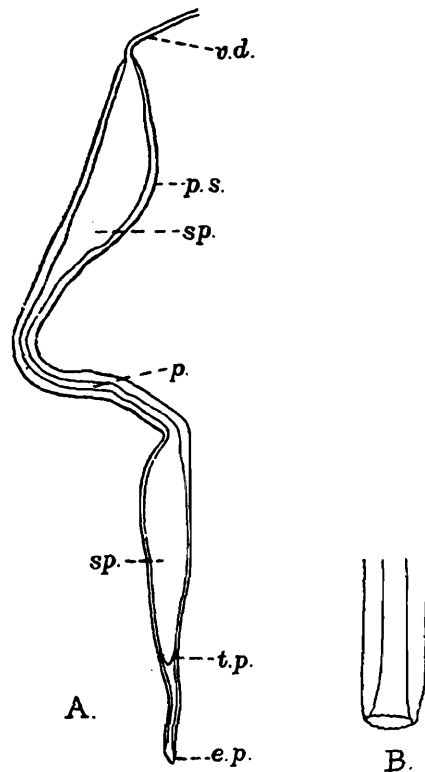


FIG. 14.—A. Penis and end of vas deferens, of *Indoplanorbis exustus* (Deshayes).

e.p. external opening; *p.* penis; *p.s.* penis sheath; *sp.* sperm duct; *v.d.* vas deferens.

B. Terminal part of the male duct of *I. exustus*.

¹ Pelseneer, *Mollusca*, in Lankester's *Treatise on Zoology*, p. 186, fig. 175 (1906).

² P. and F. Sarasin, *Sussw. Moll. Celebes*, pp. 72-77, figs. 165, 166.

³ Baker, *Chicago Acad. Sci. Spec. Pub. No. 3*, p. 199 (1911).

able number of specific names have been given to varieties and phases of *I. exustus* and we believe that all those forms, assigned to *Planorbis* (s.s.) by Preston are really synonymous, with the possible exception of *P. hindu*, Clessin. As to this form nothing is known beyond the original description and figure, and we doubt whether it is really Indian. There is, therefore, at present no evidence for the occurrence of the true *Planorbis* in India.

Distribution of the Genus.—The type-species occurs not only throughout the plains of the Indian Empire east of the Indus, but also in Siam, the Malay Peninsula, French Indo-china and Sumatra, whence we have recently examined numerous specimens.

Indoplanorbis exustus (Desh.).

1834. *Planorbis exustus*, Deshayes, *Voy. Bell. Indes Orient. Zool.*, p. 417, pl. i, figs. 11-13.
 1836. *Planorbis indicus*, Benson, *Fourn. As. Soc. Bengal* V, p. 743.
 1856. *Planorbis coromandelicus*, Clessin, *Mart. Chemn. Conch.-Cab., Limnaeacea* XVIII, p. 43, pl. vi, figs. 14-16, 20-22.
 1918. *Planorbis exustus*, Annandale, *Rec. Ind. Mus.* XIV p. 111, pl. xi, figs. 1, 1a.

In the paper cited above, one of us referred to *I. exustus* as an example of a species which, comparatively speaking, was neither variable nor plastic. When series from many different habitats are examined it becomes evident that this statement should have been qualified by some such phrase as "in normal circumstances." Specimens from ordinary ponds and swamps in India, Siam and Sumatra are very much alike, but those from pools subject to great changes in physical conditions or containing water of very abnormal chemical composition respond readily in peculiarities of shell-structure. In the collection belonging to the Indian Museum Mons. L. Germain has found a number of peculiar phases, some of which he has described as varieties.

An instance has recently come under observation in which a distinct seasonal change has been noted in the shells found in a certain pool situated on a small island and liable to considerable vicissitudes. This pool, which lies in the middle of Barkuda, a rocky island in the Chilka Lake, is a small artificial pond dug in the rock. In the latter part of the rainy season and for some time after it, roughly from the middle of July to December, it contains from 12 to 15 feet of water which is only very slightly brackish and remains fairly cool, but by April has sunk to a small puddle of saline water heated by the sun to a high temperature. The early showers which precede the monsoon in May and June fill up the pond again, not of course to its level in the rainy season, but sufficiently to give a depth of 4 or 5 feet of water and to reduce the salinity very considerably. The pond has no visible aquatic vegetation at any season, but *I. exustus* and a form of *Limnaea luteola* abound on the mud with which its rocky basin is deeply covered. Specimens of the Planorbid taken in August are fairly

normal, but rather small. The measurements of a large shell are $14 \times 11 \times 6$ mm. The colour, when the shell is clean, is a deep uniform chestnut brown, but the surface is usually covered with a black deposit. The aperture is often somewhat contracted and shows a slight tendency to be irregularly folded round the margin, and the vertical sculpture, though by no means strong, is rather irregular. The animal is apparently quite normal.

The shells taken in the middle of April are considerably smaller, the measurements not exceeding $11 \times 9.5 \times 5$ mm. The older part is like that of individuals collected in summer, but the younger part of the body-whorl, often for a length of at least 6 mm. is distinctly abnormal. In this region the shell is very thin, strongly and irregularly sculptured and often somewhat eroded on the surface and as a rule much distorted round the aperture, which is sometimes thrown into strong folds. At this season the soft parts are also abnormal. A greater part of the animal is as a rule protruded from the shell than is usual, and the mantle seems to have shrunk in such a way that the siphon and the branchial process, which is very large, are often completely exposed. The tentacles also are as a rule strongly clavate, having an oval swelling at the tip which, as its tip is densely pigmented, has much the appearance of an eye. Major R. B. S. Sewell has kindly examined specimens of these abnormal tentacles. He finds in the tissues of the swollen tips numerous individuals of a parasitic Protozoon, probably a Gregarine. Specimens taken at the beginning of June had again become normal both as regards their shell and in their soft parts. The tentacles were no longer clubbed and were free from parasites.

At least five factors may enter into the question of the origin of these changes in the shell and soft parts of *I. exustus*, namely (1) changes in the salinity of the water, (2) abnormally high temperature, (3) restricted space, (4) restricted food supply, and (5) parasitism. The production of clavate tentacles is clearly due to the last, but probably the abnormal structure of the youngest part of the shell in April is due mainly to the first two.

I. exustus is common all over the Manipur Valley, in ponds, swamps, sluggish streams and in the Loktak Lake. Specimens are for the most part normal, all the shells are of a deep chestnut brown colour when clean. Some very large specimens with the vertical ridges strongly but not excessively developed and the central region deeply depressed both above and below, were found in small artificial bathing-pools devoid of visible vegetation at the edge of the swamp to the east of the Loktak Lake. The measurements of one of these are $20 \times 16.5 \times 8.2$ mm.

Anatomy.—The foot of *I. exustus* when fully expanded is leaf-shaped, not more than twice as long as broad, very broadly rounded or subtruncate in front and bluntly pointed behind. The head is broad and short, it has an expanded and flattened lower margin and is convex above. The tentacles are not very long and are filiform. The eyes are entirely sessile and lie close to the inner

base of the tentacles. The edge of the mantle is somewhat thickened and the left epipodial lobe is well developed to form an ear-shaped incomplete funnel or pulmonary siphon. Lying externally and posterior to the siphon a secondary pallial branchial process projects outwards and backwards. When fully expanded this process is elongate, band-shaped and bluntly pointed. In longitudinal section it would be coarsely and strongly sinuate owing to alternate convexities and concavities on its surface. When contracted it has the appearance of a strongly pleated or folded foliate body; in some cases the pleats are large and appear like lamellae.



FIG. 15.—Longitudinal section of the secondary branchial process of *Indoplanorbis exustus* (Deshayes).

When contracted it has the appearance of a strongly pleated or folded foliate body; in some cases the pleats are large and appear like lamellae.

In the radula there are about 75 longitudinal rows of teeth with the approximate dental formula 26.12.1.12.26. The external marginals are, however, very ill-developed and the transition between the outer laterals and inner marginals is so gradual that

it is difficult to fix the point of separation. The free lobe of the central is large and bilobed. Its base is relatively long and narrow. The marginals have their cusps long, stout and sharp. In other respects the teeth do not offer any peculiarities beyond those noticed in the generic description.

Gyraulus, Agassiz.

1837. *Gyraulus*, Agassiz, *De Charpentier Cat. Moll. terr. fluv. Suisse; Neu. Deu. Schw. Ges. Nat.* I, p. 21.
1919. *Gyraulus*, Annandale and Prashad, *Rec. Ind. Mus.* XVIII, p. 52.

We have nothing to add to our recent account of the genus, except that Benson's species *Planorbis cantori* is not a *Segmentina*, as Preston thought, but belongs to this genus.

***Gyraulus convexiusculus* (Hutton).**

1919. *Gyraulus convexiusculus*, Annandale and Prashad, *Rec. Ind. Mus.* XVIII, pp. 52-54, figs 5E, 7a, 8b.

In the Manipur Valley the species is not so common as it is in other parts of India; and seems to be replaced to a large extent by *G. cantori*.

The only specimens collected in the valley are from a shallow pond in front of the Residency at Imphal and an artificial tank at Mingyang Pukri in the same town.

Gyraulus cantori (Benson).

1850. *Planorbis cantori*, Benson, *Ann. Mag. Nat. Hist.* (2) V p. 349.
 1876. *Planorbis cantori*, Hanley and Theobald, *Conch. Indica*, p. xviii,
 and p. 18, pl. xl, figs. 1-3.
 1878. *Planorbis (Segmentina) cantori*, Nevill, *Hand-list Moll. Ind.*
Mus. I, p. 246.
 1915. *Planorbis (Segmentina) cantori*, Preston, *Faun. Brit. Ind.*
Freshw.-Moll., p. 126.

Benson in his original description of the species specifically mentions partitions or lamellae within the shell; these like the ones described by the same author in another species (*Planorbis umbi-*

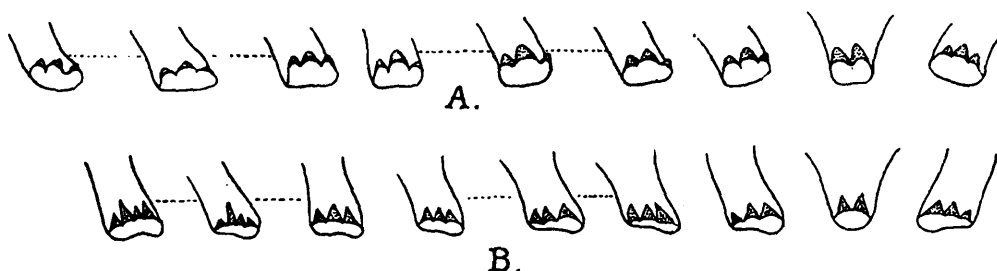


FIG. 16.—Radular teeth of Planorbidae.

A. *Gyraulus cantori* (Benson).

B. *Hippeutis* (?) *umbilicalis* (Benson).

licalis) are not to be seen in the specimens which we assign to this species. It appears likely that Benson mistook external furrows of the shells for internal septa. In other respects our specimens agree closely with his description and with Hanley and Theobald's figures of this species. The shell closely resembles that of *G. euphraticus* but is still more depressed and flattened and has an even stronger peripheral keel.

The animal resembles that of a true *Gyraulus* in all respects. The branchial process consists of a large and well-developed leaf-like pallial outgrowth in continuation of the left epipodial lobe. It is thick and highly vascular. The pulmonary siphon, which is just internal to the branchial process, is not well developed, and is formed by the epipodial lobe itself.

The radula has the dental formula 9.8.1.8.9. The central tooth is bicuspid as other species, but the cusps are rather large and pointed. The lateral teeth are tricuspid with the cusps resembling those of the central. The



FIG. 17.—Penial stylet of *Gyraulus cantori* (Benson).

marginals differ from those of *G. convexiusculus* described in a previous paper¹ in having only three or at the most four cusps.

The genitalia resemble those of *G. convexiusculus* (*loc. cit.*) in all essentials. The stylet, however, is better developed and near the tip has the margin on one side produced into a distinct triangular flap. This is one of the common species of Planorbidae in the Manipur Valley and was collected in large numbers in the Loktak Lake, and in the streams and swamps surrounding the lake.

Hippeutis, Agassiz.

1837. *Hippeutis*, Agassiz, *op. cit.*, p. 22.

1886. *Hippeutis*. Clessin, *op. cit.*, p. 34.

The shell of *Planorbis umbilicalis*, Benson, as Bavay and Dautzenberg² have observed, agrees in generic type with that of the European species of *Hippeutis*, of which *Planorbis fontanus*, Lightfoot, is the type.³ We have been unable to find any account of the anatomy of this mollusc and cannot therefore be certain as to the generic identity of the form here discussed. In both radula and soft parts it differs very widely from the Indian species of *Segmentina* and *Gyraulus*, which agree, at any rate in the genitalia, with *S. nitidus* and *G. albus*, respectively the type-species of the two genera.

In shell-characters *Planorbis caenosus*, Benson, closely resembles *H. umbilicalis*, and the two species are probably congeneric, as also appears to be the case with *Planorbis indicus* of the same author. In the account of the Fauna of the Inle Lake⁴ an unfortunate confusion between *caenosus* and *trochoideus* has occurred. The latter is certainly a *Segmentina*, while the shell of the former has no internal ridges and, as stated above, is probably a *Hippeutis*.

Hippeutis (?) *umbilicalis* (Benson).

1837. *Planorbis umbilicalis*, Benson, *Fourn. As. Soc. Bengal* V, p. 471.

1876. *Planorbis umbilicalis*, Hanley and Theobald, *Conch. Indica*, p. xviii, p. 18, pl. xl, figs. 7-9.

1878. *Planorbis* (*Segmentina*) *umbilicalis*, Nevill, *op. cit.*, p. 246.

1886. *Planorbis umbilicalis*, Clessin, *op. cit.*, p. 136, pl. xv, fig. 6.

1910. *Planorbis* (*Hippeutis*) *umbilicalis*, Bavay and Dautzenberg, *Fourn. Conchyliol.* LVIII, pp. 18, 19.

1915. *Planorbis* (*Segmentina*) *umbilicalis*, Preston, *op. cit.*, p. 125.

No septa are to be seen in the large number of both young and very large specimens of this species in the collection. The shell in other respects closely agrees with Benson's original description and the excellent figures of the species in Hanley and Theobald's work.

The external soft parts generally resemble those of *Gyraulus*

¹ *Rec. Ind. Mus.* XVIII, p. 54, fig. 8B (1919).

² *Fourn. Conchyliol.* I.VIII, pp. 18, 19 (1910).

³ See also *Fourn. Linn. Soc. London* XXXIV p. 213 (1920).

⁴ *Rec. Ind. Mus.* XIV, p. 113; also in *Rec. Geo. Surv. Ind.* L, p. 219.

except that the branchial process and the pulmonary siphon are a little better developed.

The radula is very minute with the dental formula approximately 14.12.1.12.14. The central tooth is comparatively large and bicuspid with sharp cusps. The laterals and marginals both have a peculiar twinned structure, and the line of demarcation between the laterals and marginals is not very sharp. The laterals are tricuspid, the central cusps being much the largest.

The male genitalia generally approximate to Simroth's Typus I,¹ but differ in details. The vas deferens is very long and coiled. The penis-sac is a well developed ovoidal structure with an elongate tubular preputium in continuation of the sac. The penis is massive with a lateral opening and without any stylet.

H. umbilicalis was originally described from Sylhet, Assam, but has also been recorded from Bengal in the plains of the Ganges system; it is, however, a scarce species in India proper. In the Manipur Valley it is the most abundant Planorbid, occurring in the Loktak Lake and in ponds and swamps amidst dense vegetation. In the dry swamp east of the Loktak Lake large numbers of shells, not long dead, were found in little damp pockets under masses of peat. They had evidently migrated there in hundreds as the swamp dried up.

The largest shells obtained in Manipur are from Looshipat, where they were found attached to long grass-blades in ponds with dirty water. One of them is 9.8 mm. in maximum diameter, 8.3 mm. in minimum diameter and 2.9 mm. in height.

Segmentina, Fleming.

1817. *Segmentina*, Fleming, *Conchology* in De Brewster's *Encyclopedia*, 7th ed., VII.
 1878. *Planorbis* subgen. *Segmentina* (in part), Nevill, *op. cit.*, p. 246.
 1915. *Planorbis* subgen. *Segmentina* (in part), Preston, *op. cit.*, p. 124.
 1919. *Segmentina*, Annandale and Prashad, *Rec. Ind. Mus.* XVIII, p. 56.

Preston in his account of the subgenus *Segmentina* has merely followed Nevill, and unfortunately at the time of the publication of Nevill's work nothing was known of the anatomy of these forms, shell-characters alone being used for the discrimination of the various subgenera. As a result of the study of a large collection from Manipur of some of these forms in spirit, we find that the positions assigned by Preston to several of the species are untenable. *S. umbilicalis* (Benson) is probably a *Hippeutis* and so are *S. caenosus* and *S. indicus* of the same author (see p. 584), while *S. cantori* is a *Gyraulus*.

Segmentina calathus (Benson).

1919. *Segmentina calathus*, Annandale and Prashad, *op. cit.*, pp. 56, 57, figs. 5D (wrongly printed as 5E), 7C.

¹ Simroth, *Bronn's Thier-Reichs* III (supplement), Mollusca, p. 502, fig. (1912).

In the paper cited above some anatomical details are included, there is, however, an unfortunate typographical error in that fig. 5D has the wrong lettering 5F, placed next to it, and vice versa with fig 5F.

A fair number of specimens of this species were collected at Dimapur, Assam, and at Imphal and Mingyang Pukri in the Manipur Valley. Though the shell of all these specimens is beautifully preserved, none of them have the soft parts well preserved. This was previously noticed by us in the case of the specimens from Seistan and the Punjab, and it appears that the internal partitions in the shell are in some way responsible for the poor preservation of the soft parts. The species is widely distributed and we have recently seen some specimens from Sumatra.

Camptoceras, Benson.

1919. *Camptoceras hirasei*, Walker, *op. cit.*, pp. 1-6, pl. i.
 1919. *Camptoceras*, Annandale and Prashad, *Fourn. As. Soc. Bengal*
 XIV, p. 457.
 1920. *Camptoceras, id., ib.*, XVII, pp. 27-33.

Camptoceras lineatum, Blanford.

1914. *Camptoceras lineatum*, Gude, *Faun. Brit. Ind. Moll.* II, p. 463.

To Blanford's original description of the shell, quoted with a copy of his figures by Gude, we have nothing to add, except that the spiral lines bear minute chaetae when the specimen is quite fresh or in a liquid medium.

The animal agrees with Benson's description of *C. terebra* and with Walker's figures of the Japanese *C. hirasei*. The foot is narrow and tongue-shaped, bluntly pointed behind, relatively small and not extending very much beyond the aperture of the shell. The tentacles are long and filiform but slightly clavate (? always; see p. 581), with the eyes, which are small and sessile, situated at their bases internally, the external base of each tentacle is slightly swollen. The snout is short, broad and blunt. The edge of the mantle is greatly thickened. Some distance behind the left tentacle there is a simple vascular fold—the pallial branchial process—and the opening of the branchial chamber is situated behind it. The aperture is large and, when the animal is in a half expanded condition, patent. A fold arises behind and below it on the side of the body and grows out as it proceeds forward, into a long, almost epipodial process. As the animal expands this process curls up in a spiral to form a complete branchial siphon with an inferior oval orifice, which is directed downwards, outwards and backwards. The faecal pellets are discharged through this orifice which lies immediately behind the anus. The blood is red and gives the whole animal a slightly pinkish tinge. The foot and tentacles are suffused with pale olive and minutely speckled with black and white, each of the latter has in addition an oval black area lying midway between the tips

and the bases. The snout is dark with an irregular stripe of pale specks running forward from each eye.

The radula is of the same type as that of *C. hirasei* and *C. subspinosum*, and has the formula approximately 12.9.1.9.12. The external marginals are very feebly developed. The jaw consists of a small central piece, which is rather narrow and deep, and two lateral pieces, each of which is very long and thread-like. The whole jaw is feebly chitinized. The internal anatomy is of the Planorbid type, but it is impossible for us to go into details owing to only two specimens being available. The penis-sheath, however is broad and stout with a small penis, without any stylet at the end.

Walker's figures of *C. hirasei* show the anal siphon, slightly clavate tentacles and (in a highly contracted state) the left epipodial lobe. They provide no evidence of any generic difference between the species with elongate shells and *C. lineatum*, in which the type of shell-form is much less extreme. As we have shown in another paper (*op. cit.*, p. 28) a species (*C. subspinosum*) occurs in Kashmir with a shell in some respects intermediate between the two types. We see no reason, therefore, to separate *C. lineatum* generically from *Camptoceras*.

Two specimens of this species were found crawling on the underside of floating grass-stems in a small, sluggish muddy stream that runs into the north end of the Loktak Lake near Potsengbam. They were accompanied by numerous individuals of *Ancylus viola*. Though their progression was slow and *Ancylus*-like, doubtless on account of their small foot, they showed great nimbleness in twisting the free part of the body about in the mouth of the shell. They remained submerged when placed in a vessel of clear water. The only other specimens of this species were found many years ago by Col. Godwin-Austen in what is now the Dacca District of Eastern Bengal. They were aestivating in dry weather among herbage at the edge of a partly desiccated pool and had secreted an epiphragm inside the mouth of their shells. Though the structure still remains intact, after nearly half a century, in specimens in Calcutta and London, the soft parts of the animal, at any rate in Calcutta, have completely decayed inside it.

Family ANCYLIDAE.

The taxonomy of this family is rendered difficult by the simple, probably degenerate character of the shell and by the habitual smallness of the animals. Walker, in recent volumes of *Nautilus*, has gone to great lengths in separating the species into genera and even subfamilies on microscopic characters largely in the radula. His classification is, however, impossible to apply without much labour and some residue of doubt in many cases. Some of the genera he recognizes are undoubtedly distinct, but the separation of "Ferrissinae" from the Ancyliinae is fraught with more danger than perhaps its intrinsic merit justifies, for the

radular teeth in these little molluscs can only be examined under an oil-immersion lens and even at the great magnification such a lens provides do not give an image beyond the possibilities of error in all cases. Moreover, the differences in the minute structures hardly seem to be supported by other differences of corresponding importance in the anatomy or the shell. We found it very difficult to convince ourselves, for example, that Walker was right in assigning the common Indian *Ancylus verruca* to *Ferrissia*, though there was much less doubt as to the new species here described. We propose, therefore, to retain these species in *Ancylus*, but to recognize *Ferrissia* as a subgenus and assign them to it.

In order to establish their status it was necessary to examine also the named and unnamed collections in the Indian Museum, including the specimens mentioned by Nevill in his "Hand-List." Among these we found considerable confusion. As all the species already known from the Indian Empire were represented in the collection, we take this opportunity to revise them here. Shells only of *A. baconi* and *C. tenuis* are available, but we see no reason to separate either of these species or *A. ceylanicus* from the others subgenerically and therefore assign all the Indian species to the subgenus *Ferrissia*.

The shells of these species may be distinguished by the use of the following key:—

Key to the Indian species of Ancylus.

- | | | | |
|-----|---|---|--|
| I. | Apex of shell sharply pointed, very little reflected; shell over 5 mm. long | ... | <i>A. ceylanicus.</i> |
| II. | Apex blunt, reflected to the right; shell less than 5 mm. long. | | |
| | A. | Greatest breadth of shell near the middle; outline of shell distinctly asymmetrical bilaterally | ... |
| | | | <i>A. verruca.</i> |
| | B. | Greatest breadth of shell in posterior third; outline of shell almost symmetrical bilaterally. | |
| | | i. | Sides of shell not parallel; altitude much less than $\frac{1}{3}$ of length |
| | | | ... |
| | | | <i>A. baconi.</i> |
| | | ii. | Sides parallel; altitude more than $\frac{1}{3}$ of length. |
| | | | a. |
| | | | Shell deep violet internally with minute radiating striae |
| | | | ... |
| | | | <i>A. viola.</i> |
| | | | b. |
| | | | Shell dull yellowish internally, without distinct microscopic sculpture |
| | | | ... |
| | | | <i>A. tenuis.</i> |

Genus *Ancylus*, Geoffroy.

1903. *Ferrissia*, Walker, *Nautilus* XVII, p. 15.

1917. *Ferrissia*, *id.*, *ibid.*, XXXI, p. 3.

Although Walker described *Ferrissia* as a subgenus of *Ancylus* only in 1903, he raised it to the rank of a subfamily under the name Ferrissiinae in 1917, defining it as follows:—"Jaw segmented in plates. Radula with a bicuspid central, laterals obliquely deflected with from two to five cusps arranged somewhat like the teeth of a comb; marginals also comb-like, cusps not (usually) extending to the basal line."

We have examined the radulae of *A. verruca*, *A. viola* and *A. ceylanicus*. Although the teeth differ in certain particulars from those figured by Walker in the second paper cited above, they conform sufficiently well to his description.

***Ancylus (Ferrissia) verruca*, Benson.**

1855. *Ancylus verruca*, Benson, *Ann. Mag. Nat. Hist.* (2) XV, p. 12.
 1876. *Ancylus verruca*, Hanley and Theobald, *Conch. Ind.*, pl. lxxxii, figs. 2, 3.
 1914. *Ferrissia verruca*, Walker, *Nautilus* XXVII, p. 116.
 1915. *Ancylus verruca*, Preston, *Faun. Brit. Ind., Freshw.-Moll.*, p. 105.

Specimens from Imphal, Manipur, agree fairly well with Hanley and Theobald's figures except in being rather higher, narrower and taller. There is considerable variation in these respects, however, and our specimens are smaller than the one figured in the *Conch. Indica*.

The animal closely resembles that of *A. viola*, a new species that we describe in greater detail, but has the left epipodial lobe

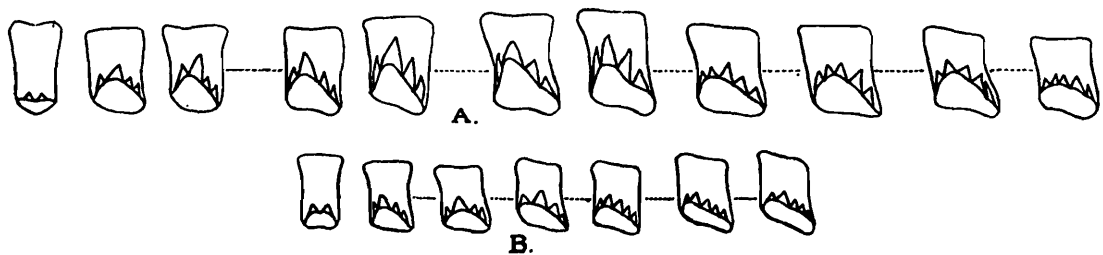


FIG. 18.—Radular teeth of *Ancylus*.

- A. *A. viola*, Annandale and Prashad.
 B. *A. verruca*, Benson.

relatively larger. We figure the radular teeth as seen under an oil-immersion lens. The mouth is a longitudinal slit provided with thin lateral lips and with a minute tongue-shaped process on the floor. The upper jaw is lunate and, though thin and delicate and somewhat broken up, has a concrete character as a whole. The majority of the side-pieces take the form of saddle-shaped denticles arranged in a long single row running parallel to and just inside the lip on either side. The uppermost piece on each side, however, is plate-like and the lowest is large and curved.

A. verruca has a wide range in the Indian Empire and Ceylon but is somewhat sporadic. In the neighbourhood of Imphal we found it not uncommon on the underside of the floating stems of water plants and leaves in ponds.

***Ancylus (Ferrissia) viola*, sp. nov.**

The shell is small and thin but opaque and of a dark brown or blackish colour. It is of suboval form, slightly narrower behind than in front and from $1\frac{3}{5}$ times to twice as long as broad-

The sides are slightly compressed, the anterior slope slightly convex and the posterior slightly concave. The apex, which is slightly eroded in the specimens examined is not greatly elevated, blunt, not at all produced or recurved, but turned a little to the right. It is situated in the posterior third of the shell. The lower margin is very narrowly flattened and sometimes obscurely retroverted. The whole of the external surface is smooth but covered in the specimens examined by a thin minutely rugulose deposit apparently of mineral origin. The interior has a dark violaceous colour owing to a bluish white glaze on the deep brown shell substance. It is marked with numerous concentric rather blunt ridges, one of which, situated about $\frac{2}{3}$ up the shell, is sharp and more prominent than the others. There is usually a band of white pigment immediately below the ridges. A microscopic sculpture of very fine straight longitudinal radiating striae can be detected under a high power, running from the inner surface of the apex to the lip. Near the margin also there are numerous transverse sinuate striae, equally minute, which give the interior of the lip a faint iridescence.

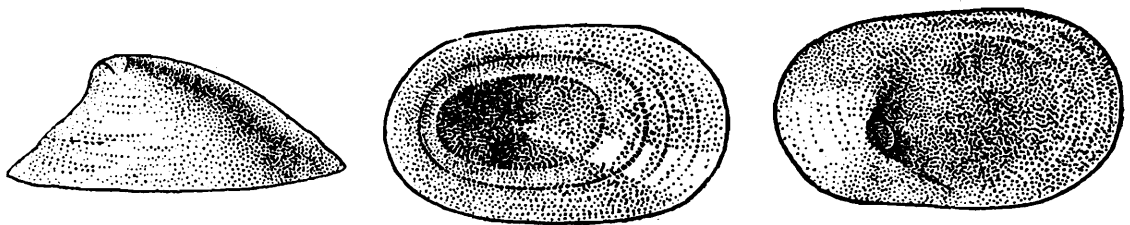


FIG. 19.—Shell of *Ancyclus viola*, Annandale and Prashad.

Measurements of Shells (in millimetres).

	A (Type).	B.	C.	D.	E.
Length	4.7	5.5	4.7	4.2	3.7
Breadth	2.5	2.8	2.5	2.4	2.5
Height	1.7	2.0	1.2	1.4	2.0

The animal is small as compared with the shell and no part extrudes in progression. The whole surface is rather opaque white with a clouding of black pigment on the head. The snout is broad and bluntly rounded in front, the tentacles short, and the eyes, which are black, are relatively large but not at all prominent. The foot is rather narrow and bluntly pointed behind. The left epipodial process is long and narrow.

The buccal mass is stout and broad. The radula is relatively large and as seen in a position of rest from above is band-shaped, narrowing abruptly behind and apparently truncate in front owing to a small anterior portion being bent downwards and inwards. The dental formula is approximately 10.8.1.8.10, but the outer marginals are very imperfectly developed and the inner marginals difficult to distinguish from the outer laterals. The jaw

resembles that of *A. (F.) verruca*, but the central piece is larger and more compact, while the lateral pieces are fewer but larger.

A short but capacious oesophagus leads to the stomach, which is divided into three regions by a very stout band of circular muscles. This band, which is interrupted on the lower surface, forms a kind of gizzard and when constricted gives the lumen of the stomach an hourglass-shape. The intestine has a precisely similar course to that of *A. fluviatilis* as figured by Simroth,¹ but we could not see any processes, in our dissections, at the point where the intestine leaves the stomach; Simroth shows them as well developed in *A. fluviatilis*. The anus is situated a short distance behind the base of the left tentacle.

The genital pore is situated immediately in front of the anus. The genitalia are imperfectly preserved in our material but the female system seems to have been better developed than the male. The hermaphrodite gland is full of large ova. The penis is short and papilliform and a flagellum is present, but considerably shorter than in *Ancylus fluviatilis* as figured by Simroth (*op. cit.*, pl. xxvi; fig. 11).

The kidney is large and occupies the anterior part of the branchial cavity.

The edge of the mantle bears numerous minute conical refractile bodies that do not seem to be of parasitical origin.

Type-specimen.—No. M 11718/2 Zool. Surv. Ind. (*Ind. Mus.*).

Localities, etc.—This species was found in abundance with *Camptoceras lineatum* on the lower side of floating grass-stems in a small, sluggish muddy stream running into the north end of the Loktak Lake, Manipur, in February, 1920. It was also taken in the same situation in a small muddy pond at Dimapur in the plains of Assam just north of the Naga Hills.

The stomach is full of mud containing the tests of numerous diatoms. The animal moves rather quickly on a smooth surface and can float shell-downwards just below the surface-film of the water.

Affinities.—The shell closely resembles that of *A. (F.) tenuis*, Bourg., from South India but may be distinguished by its brilliant internal colour and fine but distinct sculpture.

Ancylus (Ferrissia) ceylanicus, Benson.

1876. *Ancylus ceylanicus*, Hanley and Theobald, *Conch. Ind.*, pl. lxxvi, figs. 1 and 4.

Among a number of specimens of *A. (F.) verruca* from a pond in Imphal we find a single shell that agrees closely with the figures of *A. ceylanicus* in the *Conch. Indica*, which may probably be taken as a correct representation of this species. This specimen is 6 mm. long, 4 mm. broad and 2.5 mm. high.

¹ Bronn's *Thier-Reichs* III (Supplement), Mollusca, p. 338, fig. 113A (1911).

We retain this species as distinct provisionally for the animal and radula are very like those of *A. (F.) verruca*, a species also found in Ceylon, and we are not entirely convinced that it may not be simply a very old phase of the latter species, perhaps only attained occasionally. Much smaller specimens of *A. (F.) verruca* are sexually mature, but this does not preclude the possibility we have suggested.

***Ancylus (Ferrissia) baconi*, Bourguignat.**

1882. *Ancylus baconi*, Clessin, in Mart. and Chem., *Conch.-Cab., Ancylinen*, p. 61, pl. vii, fig. 7.

Among the specimens assigned by Nevill to *A. verruca*, we find a small series from Orissa that differs considerably from shells of that species and agrees well with Clessin's figure and with the original description of *A. baconi*. The species was originally described from Bengal and has since been recorded from the Philippines and Japan.

The following observation is interesting as illustrating a possible mode of dispersion. Some years ago one of us captured in the canal at Cuttack in Orissa a large Dysticid beetle the elytra of which were covered with a species of *Ancylus* in considerable numbers. The specimens were sent to the late Dr. Gwatkin and were apparently lost in transit. We are unable to say whether they belonged to this species or some other.

***Ancylus (Ferrissia) tenuis*, Bourguignat.**

1862. *Ancylus tenuis*, Bourguignat, *Spic. Mal.*, p. 208.

No figure of this species appears to have been published but large numbers of specimens that agree with the original description were recently found by one of us in small streams at the base of the Nilgiri Hills, from which the species was originally described. The specimens from South India assigned by Nevill to *A. (F.) verruca* are similar, but seem to have been completely bleached.

The species probably differs somewhat in habits from other Indian representatives of the genus. It was found on dead leaves in the pools of small hill-streams, specially those just above waterfalls.

THE AMPHIBIOUS PULMONATA (SUCCINEIDAE).

By AMIN-UD-DIN.

Genus *Succinea*, Drap.

The Indian species of *Succinea*, so far as our knowledge extends, seem to fall both anatomically and biologically into two groups; but no separation between these groups can be based on the shell-characters. Until we know more of the anatomy