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ANATOMICAL AND TAXONOMIC STUDIES OF SOME INDIAN FRESHWATER AND AMPHIBIOUS GASTROPODS

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ANATOMICAL AND TAXONOMIC STUDIES OF SOME INDIAN FRESH WATER AND AMPHIBIOUS GASTROPODS

ON THE ANATOMY OF *INDOPLANORBIS EXUSTUS* (MOLLUSCA PULMONATA)

BY H. SRINIVASA RAO, M.A.,
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In their paper on the Aquatic and Amphibious molluscs of Manipur Drs. Annandale and Prashad[1] have touched on some points in the anatomy of *I. exustus* and given reasons for establishing a new genus as different from the true *Planorbis* of Müller (with the European *Planorbis corneus* Linn., as type-species).

At the suggestion of Dr. Annandale I took up a detailed study of the anatomy of *I. exustus* with special reference to *P. corneus*, and the smaller Indian Planorbids belonging to the genera *Gyraulus*, *Segmentina*, and *Intha*. Of the latter, the Zoological Survey collection contains some amount of well-preserved unnamed material obtained by Dr. Gravely from the Central Provinces, while Dr. Annandale kindly gave me two large preserved examples of the former taken by him at Edinburgh. I have had also the opportunity of examining a small collection of the smaller Planorbids from Manipur and the Inlê lake.

My sincere thanks are due to Dr. Annandale for his constant guidance and valuable suggestions in the course of my work, and for going through the manuscript with me.

Indoplanorbis exustus (Desh.) is the largest Planorbid known in India and is widely distributed in the Oriental region. It resembles in some respects the European *P. corneus* Linn., the type-species of the genus *Planorbis*, but is well differentiated by anatomical characters.

The shell is discoidal and sinistral with the whorls convex and has a wide ear-shaped aperture.[2] The living animal usually carries the shell with the broader end of the aperture on its right and the narrower on its left. In this position the upper extremity of the shell corresponding to the spire (which is flattened in such forms) is on the animal's left, and the lower on its right. The sinistral nature of the shell can be readily recognized when it is held with the aperture facing the observer and on his left.

If the body and penultimate whorls are carefully broken off, the remaining shell, which consists of the innermost whorls, is *Physa*-like. It is noteworthy that the very young shell of *I. exustus*[3] has a similar form.

When the animal crawls in a fully expanded state the portion of the body exposed is roughly boot-shaped, with the broad anterior region

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[1] Annandale and Prashad, *Rec. Ind. Mus.*, XXII, pp. 577—582 (1921).
[2] Annandale and Prashad, *op. cit.*, pp. 578—581.
[3] Germain, *Rec. Ind. Mus.*, XXI, pp. 40-41, text figs. 12—14.

corresponding to the heel and the narrow posterior extremity of the foot to the toe, and consists of the head, foot, and neck.

The head is anterior, moderately convex, slightly longer than broad and anteriorly produced into a short, rounded snout. The lower anterior margin of the head is expanded into a flattened, roughly rectangular lobe, deeply emarginate in the middle of the anterior margin, and gradually sloping to the sides. In outline this expansion resembles that of the hammer-head shark. It is highly mobile in life, and is always extended in front of the anterior margin of the foot. The mouth is a Y-shaped or T-shaped slit in the middle of the lower surface of the head a little anterior to the foot. At the upper end of the head on each side is a moderately long, filiform tentacle, with two semicircular expansions at its base. Of the latter the outer is the larger, and is innervated by three or four branches from the tentacular nerve. The inner is smaller, and has no supply of nerves. A groove is formed between the two expansions. The male genital aperture opens at the base of the outer expansion on the left side. At the inner base of each tentacle lies the eye, which is a small spherical mass of dark pigment placed below the integument.

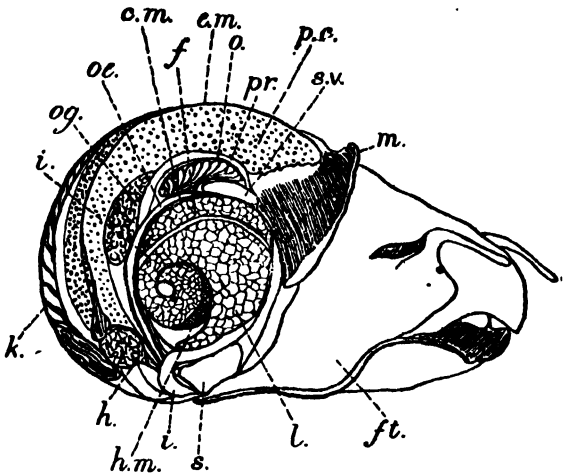


FIG. 1.—*Indoplanorbis exustus*: Viewed from the right. The right half of the mantle and the thin membrane covering the internal organs have been removed. *c.m.*, columellar muscle; *e.m.*, external membrane; *f.*, first loop of the intestine; *ft.*, foot; *h.*, heart; *hm.*, hermaphrodite gland; *i.*, intestine; *k.*, kidney; *l.*, liver; *m.*, mantle-edge; *o.e.*, œsophagus; *og.*, 'Organ de la glaire'; *p.c.*, pallial cavity; *pr.*, prostate; *s.*, stomach; *s. r.*, spermatheca.

The foot is ventral, leaf-shaped, broadly rounded in front and tapering behind.

The neck is a somewhat elongated cylindrical structure stretching obliquely backwards above the head.

The edge of the mantle is slightly thickened and does not extend beyond the margin of the aperture. At the base of the neck and on its left is a small rounded aperture through which bubbles of air may be seen to escape. This is the opening of the pulmonary siphon. Close to the narrower side of the aperture and projecting from below the

mantle is a broad roughly triangular lobe with transverse folds on its upper and lower surfaces, and with its free extremity often curled up. This is the branchial process or pseudobranch.[1] Between the pulmonary siphon and the base of the pseudobranch is the circular anal aperture. This is not clearly seen as a rule, but its position can be made out in the living animal by the occasional ejection of long threads of fæcal matter consisting of mud and sand grains.

The animal as a whole is capable of great contraction, and when disturbed withdraws itself to the inner extremity of the body-whorl. In the fully expanded animal the head, foot, and neck with the associated structures mentioned above are alone to be seen, the remaining organs of the body being confined to the inner whorls of the shell.

The body on removal from the shell may be seen to consist roughly of three regions. The anterior region includes the head, neck and foot; the middle the pallial cavity (with the pulmonary siphon and the pseudobranch), the œsophagus, the columellar muscle, the kidney and heart,

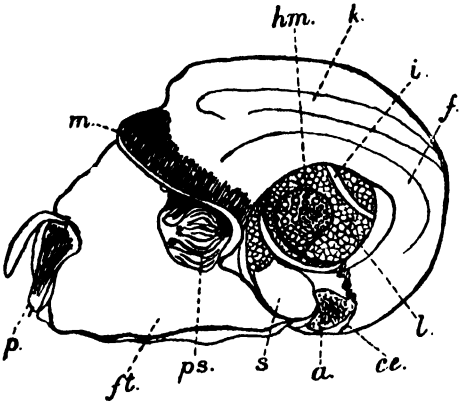


FIG. 2.—*Indoplanorbis exustus*: Viewed from the left. The thin membrane covering the inner whorls has been removed. *a.*, auricle; *ce.*, cut edge of thin membrane covering the internal organs; *f.*, fold hanging from the roof of the pallial cavity; *ft.*, foot; *hm.*, hermaphrodite gland; *i.*, intestine; *k.*, kidney; *l.*, liver; *m.*, mantle-edge; *p.*, everted penis; *ps.*, pseudobranch; *s.*, stomach.

part of the genitalia, and the rectum; and the posterior the stomach, the intestine and liver, and the rest of the genitalia. A thin membrane covers the middle and posterior regions. It is pigmented black on the middle region, and is transparent on the posterior, but the depth of colour varies in different parts of the regions, and in different individuals. On removing this thin membrane the disposition of most of the internal structures can be made out with great facility.

On the right side, the middle region has the pulmonary cavity roofed over by the tubular part of the kidney in the middle. On slitting open the pulmonary cavity on this side, part of the genitalia and the œsophagus lying above the columellar muscle may be seen. The stomach, the liver and intestine may be seen in the posterior region.

[1] The term 'pseudobranch' has been proposed by Dr. Annandale for this process, as it is quite different in structure from the typical molluscan branchiæ. I adopt this term throughout in the present description.

On the left side, a small portion of the pulmonary cavity with the rectum below may be seen in the middle region, while a portion of the liver and intestine, and the entire hermaphrodite gland occupy the posterior region.

The mantle is thin and vascular over the pulmonary cavity, and is attached anteriorly to the neck of the animal on the right of the pulmonary siphon. Its free margin is slightly thickened, smooth, vascular, and has short longitudinal muscle fibres.

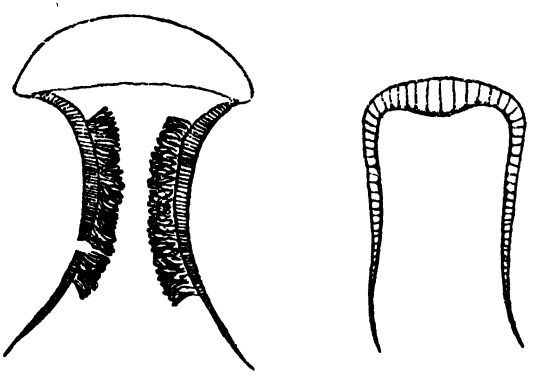
On cutting the mantle above the pseudobranch along the length of the pulmonary cavity and reflecting it to the right, it may be seen that the pulmonary siphon is formed by the broad superior pallial lobe. On its left separated by a short space lies the pseudobranch, which is the modified inferior pallial lobe. Between the two, but close to the base of the pseudobranch is the circular anal aperture. The female opening is a small round aperture at the base of the neck, and a little below the right side of the siphon. The floor of the pulmonary cavity is lined by a thin membrane which shuts off the underlying structures. This membrane is continued upwards over the posterior part of the cavity separating the structures of the posterior region from it. There are two vascular folds lying parallel to and above the rectum From the roof of the pulmonary cavity depend two vascular folds, a large one close to the kidney, and a small a little to the left. The kidney is an elongated tubular structure running obliquely from the posterior to the anterior end of the roof of the pulmonary cavity. It will thus be seen that the latter is an incompletely closed chamber communicating with the outside by means of the siphon. In the living animal it is filled with air which may be expelled when required through the siphon. The air, however, never seems to be completely expelled, a small residue being always left even in individuals killed in a contracted state.

The colour varies to some extent in different examples of the species from different localities. The head, foot, and neck are deep reddish brown, or dark grey speckled with minute yellow dots. The margin of the foot is yellowish brown. In the living condition the red blood of the spacious sinuses is responsible for the deep reddish colour, which fades frequently with the rushing back of the blood into the upper parts of the body. In preserved examples the colour is dark brown fading to a deep slaty gray. The sole of the foot is paler than the rest of the foot. The tentacles have dark spots or transverse bands, and are minutely dotted yellow. A small mass of dark pigment is sometimes found at the tip of the tentacle, and has the appearance of an eye. The mantle has a layer of black pigment above, traces of which may be seen on the membrane covering the upper whorls of the animal.

The Alimentary System.—The mouth, as has already been described, is a narrow Y-shaped slit. But it may also be T-shaped when tightly closed. When the animal feeds, or hangs upside down from the surface-film the aperture of the mouth is oval, and frequently opened and closed. A little behind the aperture are to be found the chitinous jaws, which consist of a transverse and two vertical pieces. The former is a strongly chitinised semicircular piece of a dark brown colour, which has its inferior margin uneven. The latter are less strongly chitinised, slightly curved narrow strips of a yellowish colour, and are placed one on each side close to the outer and inferior margins of the transverse piece with the concave side directed outwards and the inner convex sides often meeting in the

middle. Under a low power of the microscope they are seen to be indistinctly divided into numerous, narrow, transverse segments. Close to each of the vertical pieces on the inner side is often found a thin, yellow strip of chitinous structure which is divided into a number of club-shaped filaments directed towards the buccal cavity.

In *P. corneus* and in some species of *Gyraulus* the jaw is of the same type, whereas in other species of *Gyraulus* and in species of the genera *Segmentina* and *Intha* it is a single, narrow, chitinous strip of a yellowish brown colour bent in the form of an inverted U, and is distinctly segmented.



a *b*

FIG. 3.—*a.*, jaw of *Indoplanorbis exustus* ; *b.*, jaw of *Gyraulus* sp.

The mouth leads upwards and backwards into the narrow buccal cavity, the roof and sides of which have muscular walls, while the floor is formed by the odontophore. The latter consists of a soft but thick and tough, saddle-shaped structure supported by a pair of vertical muscle-pads. The radula lies over this structure, and stretches downwards and backwards into the radular sac, which is a short digitiform process projecting from below the posterior end of the buccal mass. When the animal actively feeds, or floats upside down from the surface-film of water, the radula is worked upwards, forwards and backwards. It is a broad chitinous ribbon with several rows of teeth, usually 77 to 83 longitudinal rows of teeth in the broadest portion of the radula, with the approximate dental formula 26.12.1.12.36. Each tooth consists of a broad basal part and an overhanging flap above bearing triangular or conical cusps on its free margin. The cusps are worn out and consequently blunt in some of the anterior rows of teeth. The marginals vary in number to some extent, while the central and laterals are always constant. The outermost lateral, which has traces of a division of the entocone into small secondary cusps, may be considered as the first marginal, and all the teeth centrad of it with only three cusps on each as the laterals. The central is small and has only two cusps slightly unequal in size. A minute cusp is sometimes seen at the base between the two. In the laterals the mesocone is the largest cusp, and the ectocone small and shorter than the rest. In the first marginal the entocone is usually divided into smaller secondary cusps, while the base

of the ectocone and the outer margin of the flap bear very minute cusps. In the second and third marginals generally the innermost cusp of the entocone has its inner base somewhat deeply divided. In the next few marginals the cusps of the entocone and the mesocone stand out in a single, more or less, transverse row with the ectocone much below the base of the mesocone. The ectocone may often be divided into two nearly equal cusps with several minute ones at its base. In all these marginals the mesocone remains unchanged and is the largest cusp. In the next few marginals the mesocone gradually becomes smaller and smaller until it is of the same size as the secondary cusps of the entocone. Some of these latter are entirely suppressed so that there are fewer cusps on an elongated, narrow body. The cusps themselves become blunt and rounded. The ectocone is also gradually reduced until it disappears. In the last few marginals the cusps are all gradually reduced until the last marginal loses all traces of them and becomes a narrow strip of chitin with its free extremity blunt and rounded.

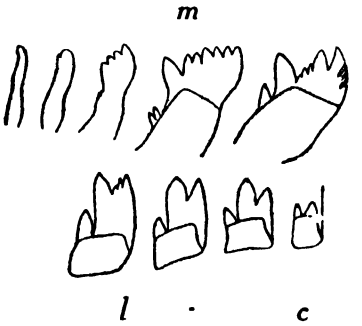


FIG. 4.—*Indoplanorbis exustus*: Radular teeth. *c.*, central; *l.*, laterals; *m.*, marginals.

A pair of salivary glands lies above, or in close relation with the male genital duct, and passes close to the inner side of the cerebro-pleural commissure to open into the buccal cavity, one on each side of the commencement of the œsophagus. Each gland is a long tube which may, for convenience, be divided into three regions. The posterior region lies behind the nerve collar and has small diverticula. It gradually narrows to a fine tube which crosses the nerve collar, and enlarges into a wide lobed sac lying on the posterior face of the buccal mass. This is the middle region. The posterior and the middle regions form the gland proper, while the anterior, which is a short fine tube commencing from the sac, is the duct. At the posterior extremity the glands of the two sides are united by a very short narrow connective.

In *P. corneus* the salivary glands are of the same type with slight differences. The saccular middle region is much larger, and is in the form of a mushroom with a large number of thin finger-shaped diverticula, while the posterior tubular region is much longer with prominent diverticula on them.

In the smaller Planorbids belonging to the genera *Gyraulus*, *Segmentina*, and *Intha* the salivary glands are much simpler and almost uniformly tubular.

The buccal cavity leads backwards and upwards to the œsophagus which commences as a median narrow tube from the top of the buccal mass near its posterior end. On leaving the buccal mass the œsophagus descends to pass through the nerve collar, and runs parallel to and on the right margin of the columellar muscle as a narrow compressed tube. It passes below the albumen gland on its right and enters the stomach. It is pigmented dull gray, and has longitudinal folds in its lumen which give it a striated appearance externally. The stomach is roughly barrel-shaped with both ends gradually tapering. The wide central part is smooth, and provided with thick, shining, transverse muscle-fibres. It has a spacious lumen filled with small grains of sand. The anterior and posterior tapering portions have longitudinal folds in the lumen.

The colour of the stomach is usually reddish pink. The intestine is a long cylindrical tube with smooth walls, and commences from the posterior end of the stomach. It turns sharply to the right and passes parallel to the stomach up to the anterior end, and then to the left bordering the anterior part of the stomach. It runs obliquely backwards in a groove on the liver towards the right side and surrounds the entire liver in a wide loop. On passing obliquely forwards nearly touching the first loop it slightly descends to emerge from the hind end of the pallial cavity as the rectum. The latter has a straight course to the anus and is roofed over by two parallel vascular folds about which mention has already been made. The intestine is usually of a dull pink colour which deepens on the rectum. A small finger-shaped cæcum is present at the commencement of the intestine in the bend formed between the latter and the stomach. Its lumen has minute longitudinal folds. The ducts of the liver which are usually four in number open into the stomach at the base of the cæcum.

The disposition of the alimentary tract is essentially the same in *P. cornens* and the smaller Planorbids, but some variations in the length and nature of the intestinal loop, and in the size of the cæcum occur in the latter. In some species of *Gyraulus*, as for instance *G. euphraticus* Mousson, the intestinal loop round the liver is either very short or totally absent, the intestine in the latter case proceeding forwards straight from the stomach instead of coiling round the liver; and the cæcum is well developed. In other species of *Gyraulus* and in *Segmentina taia* Annandale and *Intha capitis* Annandale the intestine is long and surrounds the liver more or less completely. The cæcum in these is very small, and is often overlooked.

The liver is a large brownish mass extending from the posterior end of the albumen gland up to the base of the hermaphrodite gland. It is often heavily infected with cercariæ of a parasitic trematode. Most of the individuals that I examined from Calcutta and Nagpur had the liver disintegrated to a slight extent on account of the infection. The hermaphrodite gland, being close to the liver, is also frequently affected.

The pallial cavity.—The pulmonary chamber occupies a greater portion of the body whorl, and is about a third of the length of the whole animal. The sides and roof are formed by the mantle, while the hind end is shut off from the structures of the upper whorls by a membranous partition which also paves the floor of the chamber, separating off the underlying organs, while the front end is shut off from the head by the union of the mantle with the neck. It communicates with the outside by means of the pulmonary siphon. The mantle is highly

vascular over the roof and sides of the chamber, and branching lacunæ may be seen through the pigmented membranous covering. The respiratory surface of the interior of the chamber is increased by the presence of longitudinal vascular folds projecting into it from the roof and the floor. A comparatively large thick fold commencing from about the level of the heart extends along the left margin of the kidney to the front end of the chamber, and hangs down as a vertical flap just

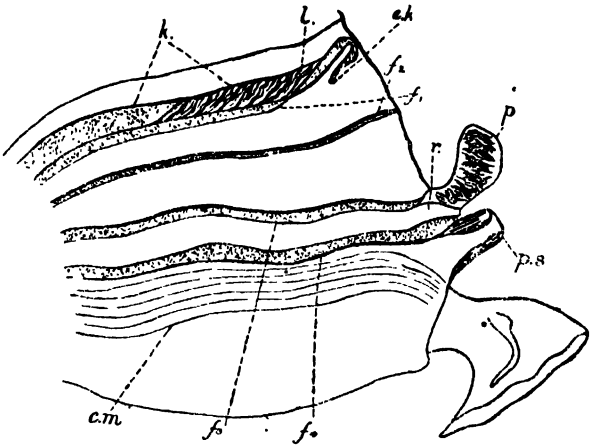


FIG. 5.—*Indoplanorbis exustus* : Mantle cut open longitudinally on the right side and reflexed to the left showing the folds of the pallial cavity. The kidney is partly opened from below to show the internal folds. *c.m.*, columellar muscle ; *e.k.*, external opening of kidney ; *f.1*, *f.2*, folds on the roof of the pallial cavity ; *f.3*, *f.4*, rectal folds of the pallial cavity ; *l.*, folds in the lumen of the kidney ; *k.*, kidney ; *p.*, pseudobranch ; *p.s.*, pulmonary siphon ; *r.*, rectum.

above the rectum roughly dividing the cavity into two chambers. It seems probable that in life, when the pulmonary chamber is distended, even this temporary division does not take place. A little to the left of the large fold is another small one lying parallel to the kidney from the hind end of the chamber to a little behind the margin of the mantle. Above the rectum and parallel to it on each side runs a prominent, thin, vascular fold, the right continuous with the left margin of the siphon, and the left with the right margin of the pseudobranch. So far as I have been able to make out in the examples of *P. corneus* before me the right fold is absent,[1] but in its place there is a broad convex ridge.

In the smaller Planorbids the vascular folds are very minute, and are found in the same positions.

Running close to the base of the renal and rectal folds are two principal veins which may be observed on removing them. Spherical calcareous concretions are found in great numbers on all the folds.

[1] Pelseneer has figured two folds above the rectum in *P. corneus*. Vide *Arch. de Biol.*, XIV, pl. xvii, fig. 27 (1895–96).

They are also found on other structures of the pallial cavity and on the walls of the vascular sinuses.

The air in the pulmonary chamber is often expelled in small bubbles through the siphon, and this act is probably an expulsion of impure air. When the animal is disturbed at the surface of the water it usually discharges a few bubbles of air with a simultaneous contraction of the body to a slight extent, and drops to the bottom. It does not rise up to the surface directly from the bottom, but crawls over weeds and other supports to the surface of water. It seems to me therefore that the pulmonary chamber is not, strictly speaking, a hydrostatic organ as well.

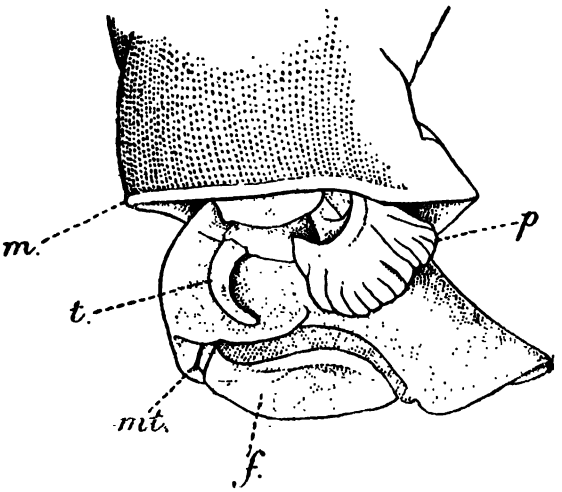


FIG. 6.—*Indoplanorbis exustus*: Left view of the anterior region showing the pseudobranch. *f.*, foot; *m.*, mantle; *mt.*, mouth; *p.*, pseudobranch; *t.*, tentacle.

The siphon is a broad thin lobe, deeply emarginate in the middle of the anterior margin, and when the sides of the lobe overlap above, a temporary tube is formed, through which the air in the pulmonary chamber escapes to the outside. Usually the whole siphon is well within the margin of the mantle, but at the time of expulsion of the air it is slowly protruded slightly beyond the edge of the mantle with its extremity expanded into a funnel. As soon as a bubble has been discharged the extremity of the siphon is flattened and is the first to touch the surface film of water. It then suddenly contracts so that the wide funnel-shaped opening is reduced to a small circular aperture, through which water does not pass into the pulmonary chamber.

In *P. corneus* the siphon is short, broad, thick and prominent. In the smaller Planorbids it is always present,[1] but varies in form and size.

[1] Drs. Annandale and Prashad have observed a spirally coiled, epipodial siphon in *Camptoceras lineatum* Blanford (*Rec. Ind. Mus.*, XXII, p. 586). A similar siphon in *C. hirasei* Walker from Japan is figured by Walker in *Occ. Papers Mus. Zool. Univ., Michigan*, no. 64, pl. 1 (1919).

In some species of *Gyraulus* it is short and broad, while in others long and narrow; and in *Segmentina taia* and *Intha capitis* it is small and less conspicuous.

The pseudobranch is a broad leaf-shaped lobe attached by its broader end below the anal opening on its left. The upper and lower surfaces are thrown out into a number of prominent pleats or folds, three or four of which are grouped together. Each group of folds is separated one from the other by a short deep gap. The free margins of the pseudobranch are not involved in the folding, but form a border to the central folded area. The colour is a dull brown or slaty gray speckled with yellow dots. In the expanded animal the free terminal portion is curled up against the edge of the mantle, or rarely of the shell. In this position the folds of the upper surface are not visible, and even when uncurled appear much less prominent than those of the lower surface. They are very complex as may be seen in transverse and

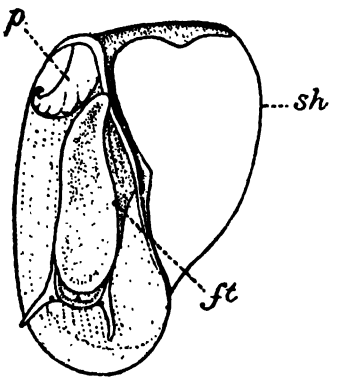


FIG. 7.—*Indoplanorbis exustus*: Ventral view of a living young specimen. *ft.*, foot; *p.*, pseudobranch; *sh.*, shell.

longitudinal sections of the pseudobranch. In several living examples that I observed the pseudobranch had its free extremity always curled up both in the expanded and contracted state.[1] It is vascular and has well developed efferent and afferent veins, and has a supply of muscle-fibres and nerves. In young individuals it has the same structure and disposition as in the adult. From its position and structure the pseudobranch appears to be an accessory respiratory organ.

In *P. corneus* the pseudobranch is a simple leaf-shaped lobe without the folds of *I. exustus*. In the examples before me it is very much contracted and hardly distinguishable as a distinct lobe owing to the effect of spirit in which they were killed and preserved. The figures of Simroth[2] and Pelseneer,[3] however, show clearly the position, form, and extent to which it can be extended. One of the chief

[1] Dr. Annandale informs me that he has observed the pseudobranch in a straight condition in living examples on the Barkuda Island under certain abnormal conditions such as foulness or salinity of the water in which they live.

[2] Simroth, in Bronn's *Tier-Reich*, III, 3, p. 453, text-fig. 152*c*.

[3] Pelseneer, *Arch. de Biol.*, XIV, pl. xvii, figs. 23, 24, 25 (1895-95).

general differences between *I. exustus* and *P. corneus*, therefore, lies in the nature of the pseudobranch.

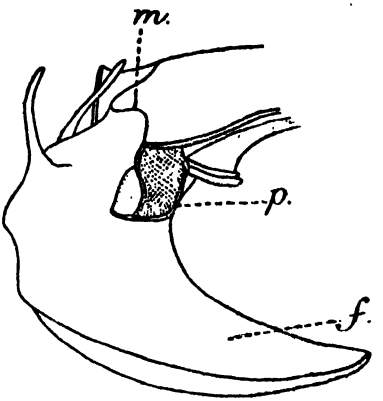


FIG. 8.—*Gyraulus euphraticus* : *f.*, foot ; *m.*, mantle edge ; *p.*, pseudobranch.

In *Pulmobranchia lamellata*[1] Pelseneer the pseudobranch is remarkably of the same type as in *I. exustus*, and in some respects the anatomy of the latter resembles more closely that of the former than *P. corneus*.



FIG 9.—*Indoplanorbis exustus* : Transverse section of pseudobranch through the anterior part.

In species of *Gyraulus* the pseudobranch is a simple, thin, leaf-shaped vascular lobe without the transverse folds. There is, however,

[1] Probably a species of *Physastra* (*cf.* Prashad, *Rec. Ind. Mus.*, XXII, p. 475).

an oblique vertical fold on the upper surface extending from the base to the free extremity. Faint transverse striations may often be seen on either side of the fold. Slight variations in the size and shape of the pseudobranch may also occur. The presence of the vertical fold apparently distinguishes the structure of the pseudobranch from that of *Planorbis* s.s.

It is curious that there is no trace of a pseudobranch in *Segmentina laia* and another unnamed species of the same genus or in *Intha capitis*. If this structure is proved to be absent in all other species of these genera it would afford an important generic distinction between them and the larger Planorbids, and indicate the close relationship of the genera *Segmentina* and *Intha*. As will be seen later these latter are closely related in anatomical characters.

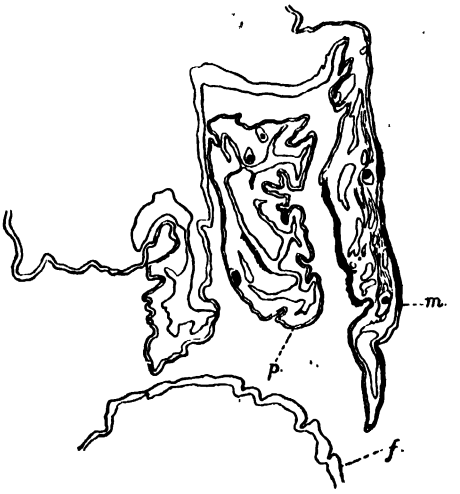


FIG. 10.—*Indoplanorbis exustus*: Longitudinal section of pseudobranch and mantle.

The vascular system.—This consists of the heart enclosed within a pericardial chamber, the thin-walled vessels carrying blood to the various organs, the so-called veins with no definite walls taking blood to the respiratory organs, and the large sinuses which place the two systems in communication. The latter are very numerous in the foot, mantle, head, pseudobranch, and folds of the pallial cavity. In preserved examples the veinous vessels have a wide lumen filled with a whitish cheese-like mass, while the others have thin, collapsed, pigmented walls with numerous calcareous concretions. The heart lies at the extremity of the pallial cavity on the right side and may be seen through the pigmented membrane of the mantle as a whitish triangular structure. The pericardial membrane is extremely thin and closely adherent to the lower surface of the mantle. The heart has the kidney on its left below and in front, and posteriorly the albumen gland and a portion of the alimentary tract. It consists of an anterior elongated roughly triangular auricle with thin spongy walls and a posterior broad

pear-shaped ventricle with somewhat thicker walls having a reticulate appearance.

From the ventricle arises a short vessel from which branches are given off to the various organs of the posterior region. The chief of these may here be mentioned. Immediately on starting from the ventricle a short branch is given off to the kidney, and a little behind, the main vessel passes over the anterior loop of the intestine, and at this point gives off a large branch which immediately divides into right and left branches. The left is a short, narrow vessel supplying the intestine, and the right on crossing the stomach gives off a short branch passing downwards between the œsophagus and the cæcum and supplying the

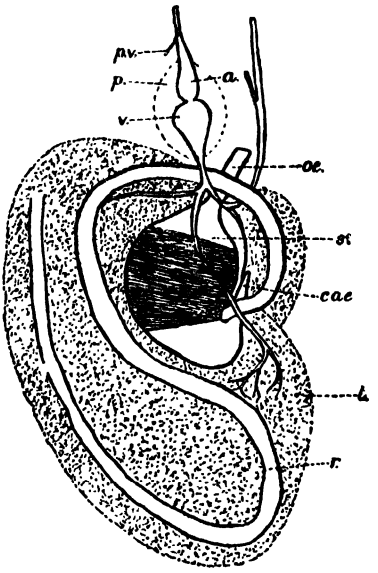


FIG. 11.—*Indoplanorbis exustus* : Circulation in the region of the stomach. *a.*, auricle ; *cae.*, cæcum ; *l.*, liver ; *oe.*, œsophagus ; *p.*, pericardium ; *p.v.*, pericardial vein ; *r.*, rectum ; *st.*, stomach ; *v.* ventricle.

stomach. It is continued on as a long narrow vessel and crosses the intestine to enter the liver, immediately dividing into smaller branches. The main vessel after giving off the branch to the intestine curves round underneath the anterior loop of the latter and proceeds straight in front below the genitalia. A small branch is given off to the cæcum from the bend of the main vessel. About the level of the albumen gland a large branch arises from the main vessel and soon breaks up into smaller vessels distributing blood to the various parts of the genitalia. The main vessel is continued below the oviduct and close to the columellar muscle below the œsophagus finally crossing the pedal commissure. Various small branches arise from it in its course to the brain. It gradually widens until it enlarges to form an elliptical sinus below the buccal mass. From the front and lower sides of this sinus fine branches reach the foot and the anterior part of the head. A small vessel from the sinus supplies the penis-sheath closely following the course of the nerve.

The veinous circulation is difficult to make out satisfactorily in freshly killed examples, and even in well-preserved individuals the thin-walled veins are usually damaged. The course of the veins can, however, be traced by the presence of a whitish, coagulated, cheese-like mass in them. So far as my observation goes the veinous circulation closely resembles that of *Pulmobranchia lamellata*.[1]

On the right margin of the kidney, commencing from the anterior end, lies the renal efferent vein which is in close relation with the highly vascular roof of the pulmonary chamber on its right. This vein at its posterior extremity opens into the auricle and at its junction with the latter, a small short branch is given off to the pericardial membrane on the right side. On the left margin of the kidney lies the renal afferent vein, which breaks up into several minute capillary-like vessels below the transverse folds of the kidney. The blood is distributed to the renal efferent vein by means of a similar set of vessels on the right margin of the kidney.

The renal afferent vein has its origin in a closed sinus in the mantle at its junction with the neck of the animal. The right pallial vein, running parallel to the edge of the mantle a little behind it, and the efferent pseudobranchial vein, which runs along th ight border of the pseudobranch and then below the base of the siphon, empty themselves into the closed sinus. The rectal vein which runs close to the rectum on its left is joined by the left pallial vein at the base of the pseudobranch and enters the left border of the latter as the pseudobranchial afferent vein, which breaks up into smaller branches among the folds of the pseudobranch. I have been unable to make out the course of the sub-intestinal vein, which runs parallel to the rectum on its right. It probably joins the left pallial vein at some point above the pseudobranch or breaks up into sinuses in the mantle.

It will thus be seen that the pseudobranch is an important organ of respiration. It receives veinous blood from the left side of the animal and, after aerating it, sends it on to the large dorsal sinus, which receives aerated blood from the mantle and the vascular roof of the pulmonary chamber.

The renal system.—This organ consists of a posterior saccular and an anterior tubular region. The former is a pear-shaped body lying immediately above the albumen gland and separated from the latter by a thin membrane. On its right a little in front lies the heart on a slightly higher level, while on its left the hind extremity of the pulmonary chamber. It has the liver on its posterior side. Its lumen is narrow on account of the presence of a number of longitudinal folds, which are yellow in colour in the freshly killed animal. The tubular region of the kidney commences from the neck of the saccular part, and extends obliquely forwards on the roof of the pulmonary chamber, as a broad compressed tube up to the junction of the mantle with the neck. It then curves sharply to the left as a short narrow arm directed backwards, and carries at its extremity the minute renal aperture. In some preserved individuals the renal aperture is distinctly slit-like and provided with a pair of tumid lips. In *P. corneus* the external opening of the kidney is a circular aperture on a prominent papilla.

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[1] Pelseneer, *Arch. de Biol.*, XIV, pl. xv, fig. 14 ; pl. xvi, fig. 22.

The floor and roof of the tubular part of the kidney are raised into a number of short digitiform processes or vertical folds arranged in more or less equidistant transverse rows. These folds are lined by cubical cells which give them a moniliform appearance in sections.

The reno-pericardial opening is minute, and is found as a very short, backwardly directed, tubular passage at the neck of the saccular portion of the kidney on its right.

The Reproductive system.—The male and female ducts are separate, each having a distinct opening to the outside. The position of these openings has been described in connection with the external features.

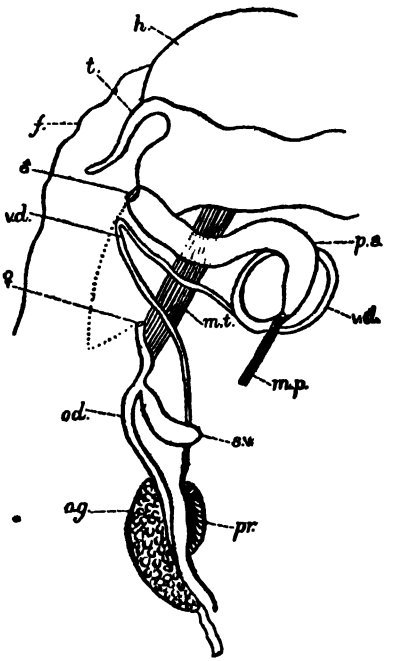


FIG. 12. - *Indoplanorbis exustus*: Anterior part of the genitalia. *f*, foot; *h*, head; *mt.*, retractor muscle of the tentacle; *m p*, retractor muscle of the penis; *od.*, oviduct; *og.*, "Organe de la glaire"; *pr.*, prostate; *ps.*, penis sac.; *sc.*, sperma theca; *vd.*, vas deferens.

The various parts of the reproductive system are essentially the same as in *P. corneus*.[1] But differences of considerable taxonomic value occur in the structure of the terminal portion of the male duct.

The hermaphrodite gland is an elongate triangular body lying coiled at the apex of the spire, when viewed from the left. The colour is a bright orange or yellowish brown in the freshly killed individual. The apex of the gland is tightly coiled and occupies the top of the spire, while its base is in close contact with the posterior extremity of the liver. The gland consists of a number of small finger shaped processes

[1] A good description of the reproductive system of *P. corneus* with an excellent plate is given by Baudelot in *Ann. Sci Nat.*, XIX, pp. 197—203, pl. iv, figs. 2—5 (1863).

opening into a median, narrow, hermaphrodite duct below. A few small ovate eggs with a single, rounded nucleus in the centre are often found in sections of the gland. Clusters of spermatozoa with long tails are often found in the spaces between the ova. They are more deeply stained than the latter. The hermaphrodite duct, on leaving the gland, is continued obliquely forwards below the liver, and at the level of the stomach passes upwards to the albumen gland situated just in front of the former. The proximal portion of the duct has very small diverticula opening into it.

The hermaphrodite duct joins a short duct from the albumen gland. A little in front of the junction of the two ducts the male and female ducts can be distinguished. The albumen gland is a dark gray fan-shaped body convex above and concave below. It has its posterior border broadly rounded while its anterior is deeply concave. The two ducts arise from below this concavity and run close together parallel to the œsophagus on its left. The ducts and the associated glands lie on the right half of and below the pulmonary chamber separated from the latter by a thin membrane. The male duct is narrow and lies below the oviduct and in close contact with it. The female duct is large and has thin walls. It passes below a large oval gland in front, called the "Organe de la glaire" "the gelatinous secretion of which appears to serve the purpose of preserving the ova from contact with water." It is broad and flattened, and has a striated appearance. There is no definite duct by which the products of the "Organe de la glaire" are led into the oviduct, apparently the gland opens into it by means of numerous small pores. The oviduct on emerging from below the gland is slightly enlarged, but soon becomes narrowed into a short, cylindrical tube into which opens a pear-shaped sac by means of a short duct. This sac is called variously the copulatory pouch, the seminal vesicle, or the receptaculum seminis. It has thin walls, and is usually filled with an orange-coloured fluid. The duct of the seminal vesicle varies in length. In not a few individuals it is very short, but occasionally examples with long ducts are also to be met with. Baudelot's figure of the genitalia of *P. corneus* shows the duct to be long, but he does not mention whether any variation occurs in this species. The oviduct in front of the junction of the seminal vesicle with it is a short duct with fairly thick walls and opens to the outside a little below the pulmonary siphon.

The male duct, as has been described above, passes close below the oviduct and to the right margin of the "Organe de la glaire," and near the anterior end of the latter receives the flattened, elliptical prostate gland, which is closely pressed to the right anterior margin of that organ. The male duct passes below the prostrate, receiving its products, and is continued forwards as a very fine rounded tube. The prostate gland consists of a large number of diverticula closely bound together and hardly distinguishable as such. It has no definite duct, and probably like the "Organe de la glaire" opens by means of minute pores into the flattened male duct below. The vas deferens is long and coiled, and on leaving the prostate runs nearly parallel to the oviduct, and passing close to the female opening proceeds in front to the integument near the male opening. It then curves sharply backwards as a somewhat wider tube. It crosses the tentacular retractor muscle, and running parallel to the penis-sheath lies coiled up behind the buccal mass, and

finally joins the penis-sheath. A single retractor muscle[1] arises from the left half of the columellar muscle, and running between the coils of the vas deferens joins the terminal portion of the latter just before it reaches the penis-sheath. It is usually smooth and shining but may be dark gray owing to the presence of a small blood-vessel which is frequently pulled off in cleaning the muscle.

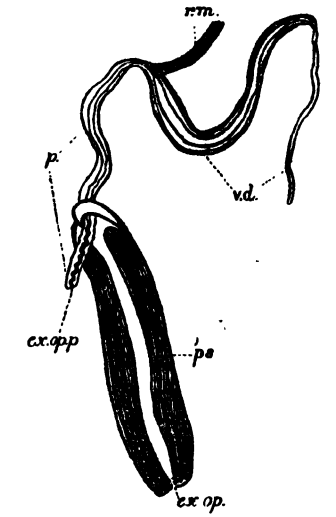


FIG. 13.—*Indoplanorbis exustus*: Male genitalia. The penis-sac and the vas deferens are cut open. *ex. op.*, external opening of penis-sac; *ex. op. p.*, external opening of penis; *p.*, penis; *ps.*, penis-sac; *r.m.*, retractor muscle of the penis; *v d.*, vas deferens.

The penis-sheath is a long, stout, cylindrical, muscular organ lying close to the integument posterior to the left tentacle. It is covered over by a thin, black membrane, and is held in position by short, thin muscles and shredded membranes above and below. The lumen of the sheath is somewhat compressed, and has on each side an elongated muscular pad. Between these pads hangs the long tubular penis, which is often broken or else extremely contracted in preserved examples. Though contracted into the upper part of the sheath it maintains a cylindrical form. It has thin walls and is continous with the thin zig-zag tube in the lumen of the vas deferens. It is often as long as the sheath itself, and has at its free end a minute circular opening. The outer wall of the penis is continuous with the tube inside it at the external opening. In preserved individuals the penis-sheath undergoes great contraction and is consequently stout and bulbous with part of the vas deferens everted into it; or it may be completely protruded inside out from the external opening with the penis at its extremity; or everted with the pads curled out on each side of the external opening with even a part of the vas deferens protruded in the centre.

[1] Drs. Annandale and Prashad evidently overlooked this muscle. In a later paper the former mentions two retractor muscles, but it is probable that the small blood-vessel and nerve supplying the penis sheath, and reaching the same point on the vas deferens as the retractor muscle, were mistaken for a second muscle.

In *P. corneus* the penis-sheath is short and stout, and the penis appears to be developed as a stout invaginated process from the walls of the sheath and has an open groove-like duct opening on a glans-like apical structure. There are two well developed retractor muscles divided terminally into two or three short branches. One of them is attached to the sheath, while the other to the terminal part of the vas deferens, a branch of which goes to the penis-sheath.

It will be seen, therefore, that the essential differences in the genitalia between *I. exustus* and *P. corneus* lie in the form and structure of the penis, and in the number and arrangement of the retractor muscles.



FIG. 14.—*Indoplanorbis exustus*: Penis (Highly magnified).

Buchner[1] recognises four types of penis in the Planorbidae. It is evident that the type in *I. exustus* is not identical with any of Buchner's, though closely allied to his third type. I agree, therefore, with Dr. Annandale[2] in recognising a fifth type represented by the penis of *I. exustus*.

The reproductive organs of the smaller Indian Planorbids (*Gyraulus*, *Segmentina* and *Intha*) have the same arrangement as in the larger forms but differ in some respects, chiefly in the structure of the genital glands and the penis. In these forms the hermaphrodite gland is usually long, and consists of longer and more distinct digitiform processes than in the larger Planorbids. The albumen gland has an irregular outline, and is much less compact than that of *I. exustus* or *P. corneus*. It has long diverticula, and is of a pale white colour. The prostate gland is remarkably different. It is an elongated, flattened structure consisting of a few, usually eighteen to twenty, long club-shaped processes arranged in a linear row alongside the vas deferens, each opening individually into the latter. The penis-sheath is not covered by a pigmented

[1] Buchner, *Jahreshefte d. Vereins f. Vaterl. naturkunde in Württemburg*, XLVII, pp. 68-69, pl. vi (1891).

The figures are reproduced by Simroth in Bronn's *Tier-Reich*, III, 3, p. 502. I am indebted to Dr. Prashad for drawing my attention to the first named reference.

[2] Annandale, *Rec. Ind. Mus.*, XXIV, p. 359 (1922).

membrane, but is more or less transparent. It is broad posteriorly and gradually narrows anteriorly, where it has a bulbous swelling, which is continued as a short cylindrical tube to the external opening. The penis is long, and in *Gyraulus* bears at its free end a reddish brown chitinous stylet. There is only a single retractor muscle attached to the penis-sheath near the bulbous swelling. In *Segmentina laia* and *Intha capitis* both the bulbous swelling and the penial stylet are absent. The structure and arrangement of the rest of the genitaila are the same as in *Gyraulus*.

The muscular system.—This consists of the columellar system extending antero-posteriorly on the ventral surface of the animal, and the muscles of the buccal region. The former is a broad sheet of muscle consisting of thin and thick fibres, and gradually narrowing towards the posterior end near the apex of the spire. Anteriorly the fibres are very closely arranged. On the ventral side of the greater part of the body-whorl the columellar muscle can be divided into a broad, median, almost transparent region consisting of thin fibres, and a narrow whitish, shining region on each side of the former consisting of thick fibres. From the columellar muscle arise two pairs of muscles, namely, the retractors of the foot, and of the buccal mass. The single retractor muscle of the penis takes its origin from the left side of the columellar muscle. Each retractor of the foot consists of thick fibres and comes off from the lateral region of the columellar muscle. It is closely adherent to the integument, somewhat narrow at its origin but gradually widening towards the antero-lateral part of the foot, which it supplies. A few fibres from the left retractor of the foot pass obliquely towards the left, close to the base of the pulmonary siphon and supply the pseudobranch. A broad sheet of thin fibres extends from the retractor of the foot on each side to the base of the tentacles. This is the tentacular retractor muscle. Two long narrow strips of shining muscle have their origin at about the middle of the columellar muscle one on each side of the central transparent region, and proceed forwards parallel to the visceral nerves. They pass through the circum-œsophageal nerve-ring close to its sides, and reach the ventro-lateral surface of the middle of the buccal mass. These are the buccal retractors. The penial retractor muscle is a slender muscle with minute fibres and has its origin at the junction of the median and lateral areas of the columellar muscle on the left side. It proceeds forwards and upwards between the coils of the vas deferens, and is attached to the terminal portion of the latter.

The buccal mass is also supplied with intrinsic muscles, the chief of which may be mentioned. Posteriorly, near the ventral surface of the buccal mass a fan-shaped muscle takes its origin, and passes obliquely forwards and upwards widening gradually in its course to the top of the buccal mass, and joins with its fellow of the opposite side in a broad, transverse band of muscle fibres across the anterior half of the buccal mass. Below this fan-shaped muscle is a broad band with fibres running concentrically round the buccal mass. It extends behind the fan-shaped muscle, and is tucked in to form a groove in the median ventral surface. A small band of muscle from the sides of the buccal mass a little behind the buccal ganglion passes forwards to the anterior end. Besides these larger muscles there are fine stands arising from above and below the buccal mass, which are attached to the integument of the snout and head above, and to the foot below.

The nervous system.—A full account of the nervous system of *P. corneus* has been given by Lacaze Duthiers.[1] So far as I have been able to ascertain, the nervous system of *I. crustus* agrees in every particular with that of *P. corneus*. The cerebral, pleural, and pedal ganglia form the circum-œsophageal nerve-ring behind the buccal mass near its ventral surface. The visceral ganglia are also found close together and united with the pleural ganglia. They present a granular appearance, and are usually of a pink or yellowish brown colour in the freshly killed individuals. The buccal ganglia are a pair of small, roughly triangular bodies placed close to the sides of the œsophagus at its commencement from the buccal mass, and connected by a short nerve-commissure below the œsophagus. From each of the buccal ganglia arise five nerves. From the outer angle in front is given off a small nerve to the salivary gland, and from the inner angle close to the beginning of the buccal commissure is given off a short fine nerve to the posterior face of the buccal mass. From the outer angle below arise three nerves of which two pass close to the sides of the buccal mass, while the third proceeds backwards to join the anterior ventral surface of the cerebral ganglion. The cerebral ganglia are somewhat elongated triangular bodies united by a short commissure above the œsophagus, the two together forming a horse-shoe shaped structure. They are broader near the middle and slightly taper towards the sides. From these arise the nerves to the tentacles, eyes, otocysts, skin and muscles of the head and snout. The tentacular and optic nerves together with those supplying the skin and muscles of the head and snout are given off from the lower outer angle of the cerebral ganglia. At the base of the tentacle a few small branches from the tentacular nerve supply the semicircular expansions on the outer side. The optic nerve is fine and is united with the tentacular nerve for some distance. The eye is simple in structure, and has a central spherical lens surrounded by a thick layer of black pigment. The nerve to the otocyst is very short and minute and recognised only in balsam mounts. It starts from the posterior face of the cerebral ganglion and proceeds parallel to it until at its outer angle it sharply turns downwards to join the otocyst. The otocyst is a minute, whitish, spherical mass at the posterior outer angle of each pedal ganglion. Its cavity is filled with numerous elliptical otoliths. From the outer extremity of the left cerebral ganglion arises a long thin nerve which runs backwards to supply the penis-sheath. The pleural ganglia are small squarish bodies placed ventral to the cerebral ganglia. The pleuro-pedal and the cerebro-pedal commissures may be seen in front of the pedal ganglia at their outer angle. There are three visceral ganglia somewhat unequal in size and arranged in the form of a U. They are roughly four-sided bodies placed close together dorsal to the pedal ganglia and behind the cerebral. From the left visceral ganglion is given off a fairly stout nerve from which branches arise supplying the pulmonary siphon, the pseudobranch, and the left side of the mantle. A little above the origin of this nerve a small branch proceeds upwards in the mantle where it joins the neck of the animal, and supplies the osphradium situated next to the right border of the siphon. The osphradium, also known as the organ of Spengel or Lacaze Duthier's new organ of innervation, is a flask-shaped structure

[1] Lacaze Duthiers, *Arch. Zool. Exp.* I, pp. 476–482 and 484–487, pl. xx; also pp. 155–156, pl. iii, figs. 9–10 (1872).

of whitish colour opening by means of a broad, funnel-shaped aperture to the outside. The nerve supplying it enters the broad end of the structure. From the middle visceral are given off three nerves, branches of which supply the floor and roof of the pallial cavity. A long nerve passes over the 'organe de la glaire' supplying the genital organs and the pericardium. From the right visceral are given off two nerves, a small nerve to the œsophagus and a stout one to the right side of the mantle. The pedal ganglia are flattened quadrilateral bodies rounded posteriorly, and give off three or four stout nerves with several branches supplying the foot. A short commissure connects the left visceral ganglion with the pallial nerve from the middle visceral.

In spite of the greater development of the pseudobranch in *I. exustus* its nerve does not seem to be any better developed than in *P. corneus*.

ON THE COMPARATIVE ANATOMY OF ORIENTAL VIVIPARIDÆ

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The members of the family Viviparidæ were, until recent years known chiefly by their shells, though a few observations on the soft parts had also been made. There are at present no sufficient data on which could be based a comparative study of the anatomy of the various species described. In the last half century various fragmentary accounts of the anatomy of *Vivipara bengalensis* (Lamarck) had been published, but so far as I know there was no single Palaearctic or Oriental species of Viviparid in which the anatomy in all its details had been completely studied. This gap in our knowledge was first filled in India by the publication in 1921 of a monograph on *Vivipara bengalensis* by Dr. Annandale and Major Sewell[1]. Their observations on certain structures in the mantle edge of this and other species and genera of the family led Dr. Annandale to important and far-reaching conclusions in respect of the sculpture and ornamentation of the shell.

These authors stated in the summary of their account that the anatomy of the Viviparidæ, so far as it had been studied is strikingly uniform in most respects. Their detailed observations were, however, apart from *V. bengalensis*, restricted to the structures of the mantle, the brain, and the radula of various species. With a view to examine their statement I undertook, at the suggestion of Dr. Annandale, to make a comparative study of other system of organs. The material placed at my disposal was all preserved, but I have had opportunities of studying fresh and living specimens of the Burmese genus *Taia* and of *V. bengalensis*. A few species from China and Japan were available for comparison in preserved material. Part of the Indian and Chinese material was in a bad state of preservation. Disadvantageous as are preserved specimens for a satisfactory study of the anatomy, I have not hesitated to place together my notes, in the hope that a small attempt in this direction may, at least, be an incentive to an extended and more exhaustive study of the family.

For purposes of comparison structures in which there is appreciable variation have been examined in all the species.

I take this opportunity of expressing my great indebtedness to the late Dr. Annandale for the help received in the preparation of this paper.

The comparative anatomy of the following five genera of Viviparidæ was studied in greater or less detail :—

Vivipara Montfort.
Taia Annandale.
Dactylochlamys gen. nov.
Lecythoconcha Annandale.
Margarya Nevill.

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[1] Annandale and Sewell, *Rec. Ind. Mus.*, XXII, pp 215—292, pls. i—iii (1921).

Vivipara Montfort.

I have examined three species of this genus, viz., *Vivipara bengalensis* (Lamarck), *Vivipara dissimilis* (Muller) and *Vivipara quadrata* (Benson). The two former are from India and the last from China. The three species belong to different sections of the genus, namely, the *Viviparae bengalenses*, the *Viviparae dissimiles*, and the *Viviparae angulares*. The alimentary organs, the kidney, and the central nervous system are quite uniform and do not show any appreciable variation. Specific differences are found only in the gill-lamellæ, in the central nervous system[1], in the male genitalia[2] and in the number of embryos present in the uterus. The differences in the form of the gill-lamella in the three species are best appreciated by a reference to the figures. In *V. bengalensis* the uterus is cramped with numerous fully-developed embryos, and eggs enclosing small embryos in various stages of development. In *V. dissimilis* there are only four to five embryos and about thirty small polygonal eggs in the uterus. The embryonic shells have no bands on them, but bear three rows of chaetae with a few prominent ridges. Some of the secondary ridges on the body whorl also bear chaetae. In *V. quadrata* the uterus contains two or three relatively large embryos without bands on their shell, and about sixteen eggs. These differences in the three species seem to be constant.

The type genus *Vivipara*, therefore, has the following anatomical characters:—

The margin of the mantle in the adult is moderately thick and bears three short processes corresponding in position with the three rows of chaetae on the embryonic shell. These chaetae usually disappear on the adult shell. The adult shell may or may not bear coloured bands and is usually without ridges or spines of any kind, but a few species are highly sculptured. The head of the animal is small in relation to its size. The gill-lamella is usually broad and has a well-developed blood vessel on its superior margin. In the central nervous system the cerebral ganglia are better developed than the pleural or the pedal, the pleural ganglia being usually insignificant and placed near the cerebral. The commissures and connectives are relatively short and thin. The uterus usually contains a large number of embryos in various stages of development.

Taia Annandale.

The following five species of the genus were examined :—

Taia naticoides f. *intermedia* Annandale;
Taia shanensis (Kobelt).
Taia elitoralis Annandale.
Taia intha Annandale.
Taia crassicallosa Annandale and Rao.

All the five species are from the Shan plateau in Burma.[3]

The genus *Taia* is distinct from *Vivipara* not only in the shell but also in the soft parts. It differs from the latter in the head of the animal being larger, in the relatively narrow marginals of the radula, in

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[1] Annandale and Sewell, *op. cit.*, p. 269.
[2] *Id.* *ibid.*, pp. 232-233.
[3] Annandale, *Rec. Ind. Mus.*, XIV, pp. 123—137, pls. xv- xviii (1918).

the lining of the stomach being transversely folded and often chitinized as two ridges at the junction of the œsophagus and the stomach, in the relatively narrow and tapering gill-lamella, in the greater development of the ganglia and commissures of the brain, and in the much fewer full-grown embryos in the uterus.

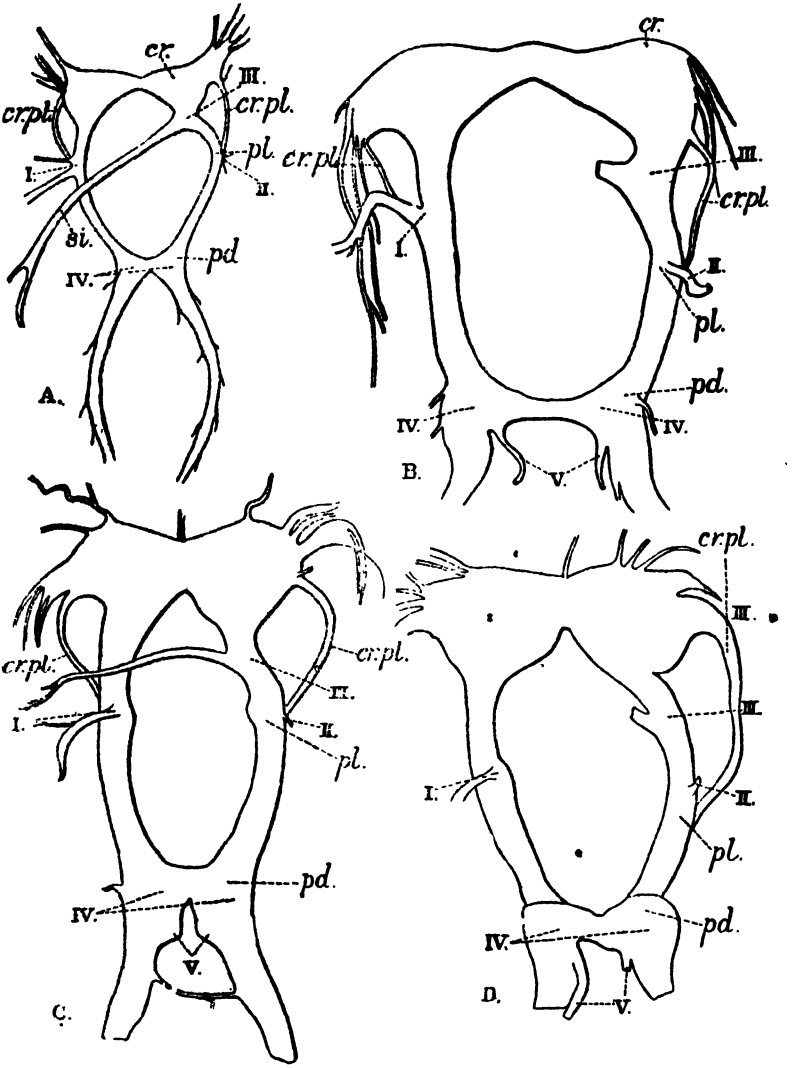


FIG. 1. – Central nervous system of Viviparidæ.

A *Viripara bengalensis*. C. *Taia shanensis*.
B. *Taia naticoides* f. *intermedia*. D. *Taia intha*.

cr., cerebral ganglion ; *cr. pl.*, cerebro-pleural commissure ; *pl.*, right pleural ganglion ; *pd*, pedal ganglion ; *si.*, supra intestinal nerve ; I., left pleural ganglion ; II., nerve from the right pleural ganglion ; III, ganglion from which the supra intestinal nerve arises ; IV., portion of pedal ganglion from which the pedal commissure takes its origin ; V. nerve from the posterior side of the pedal ganglion.

Specific differences are found in the gill-lamella, the stomach and the genitalia. Of these the most reliable are those of the gill-lamella. Other structures such as the radula, the kidney, the heart, and the brain are subject to considerable variability in the individuals of a species. Specific differences have been discussed by Dr. Annandale and myself in a paper on the aquatic gastropods of the Inlê watershed published immediately before this [1].

Dactylochlamys gen. nov.

This genus is here proposed for the Assamese and Burmese species *Paludina oxytropis* Benson. It may be defined thus :—

The shell is of large size, conical, thin but ornamented with prominent smooth spiral ridges which are concave on the internal surface. The base is somewhat flattened. The umbilicus is broadly rimate with a broad channel descending downwards from it.[2]

The radula and operculum are as in *Vivipara*. The mantle has enlarged and highly vascular finger-shaped processes on the margin.

Type-species.—*Paludina oxytropis* Benson.

Dactylochlamys oxytropis[3] (Benson).

Specimens of this species in the collection are in such a bad state of preservation that the alimentary organs, the kidney, and the genitalia

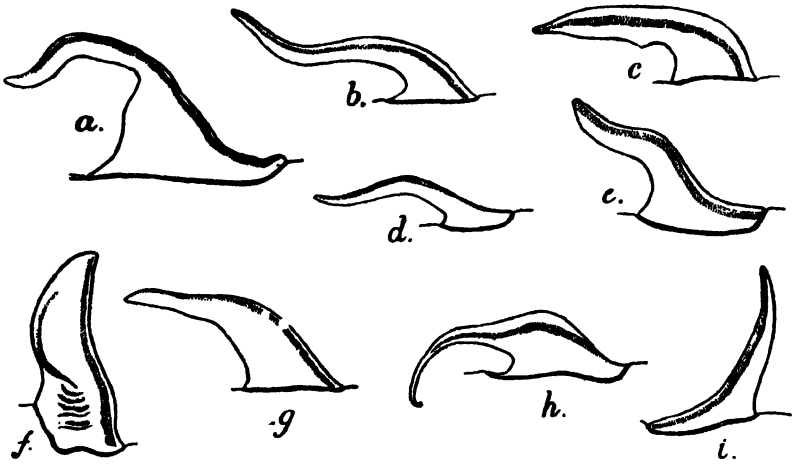


FIG. 2.—Gill-lamellæ from the middle region of the ctenidium of Viviparidæ.

a. Dactylochlamys oxytropis.
b. Taia crassicallosa.
c. Taia shanensis.
d Taia natioides f. *intermedia.*
e. Taia elitoralis.
f. Vivipara bengalensis.
g. Vivipara dissimilis.
h. Taia intha.
(i) Vivipara quadrata.

could not be made out.[4] Fresh specimens were, however, dissected by Dr. Annandale who states that there is no material difference in the

[1] Annandale and Rao, *Rec. Ind. Mus*, XXVII, pp. 119—125 (1925).

[2] See Annandale, *Rec. Ind. Mus.*, XXII, pp. 548—550, fig. 3-B, pl. iv, figs. 2—5.

[3] *Paludina oxytropoides* Heude is probably a synonym of this species, at any rate, it may be no more than a Chinese race of it. See Heude *Mem. Hist. Nat. Emp. Chin.*, p. 176, pl. XL, figs. 3 3-a. (Chang-Hai 1890.)

[4] The specimens were hardened in formalin, which, as experience has taught us, should be avoided in the preservation of freshwater molluscs.

gross internal anatomy of *V. bengalensis* and *D. oxytropis*. I have been able to examine the gill-lamellae, the central nervous system, and the uterus of the present species. The gill-lamella approaches that of *V. dissimilis* but is distinct in having a broad basal portion, and a long finger-shaped apical half. The brain is very similar to that of the species of *Taia* in the well-developed ganglia and the stout commissures. In the uterus there are about ten relatively small full-grown embryos and an equal or a slightly larger number of eggs with a tough external covering of albuminous material. The embryonic shells bear three rows of chaetae but no bands.[1]

In respect of the gill-lamella and the number of embryos in the uterus the present species may be said to be distinct from those of *Vivipara* or *Taia*.

Lecythoconcha Annandale.

This genus closely resembles *Vivipara* in some features, but has distinctive characters in the mantle, in the gill-lamella, and in the brain of the animal.

The free edge of the mantle is greatly thickened with a strong and conspicuous sphincter muscle along it. The gill-lamella is relatively long and has its superior margin thickened and often thrown into folds. The ganglia and commissures of the brain are strongly developed, much more so than in species of the genera discussed above. There are usually about thirty embryos in the uterus.

I have examined the following three species of the genus, all from outside Indian limits :—

Lecythoconcha lecythis (Benson)—(rice field phase) from China and Japan.

Lecythoconcha chinensis f. *catayensis* (Heude) from China.

Lecythoconcha sclateri (Fraunfeld) from Japan.

These three species are closely similar in respect of the soft parts but differ in the form of the gill-lamella and in the number of embryos

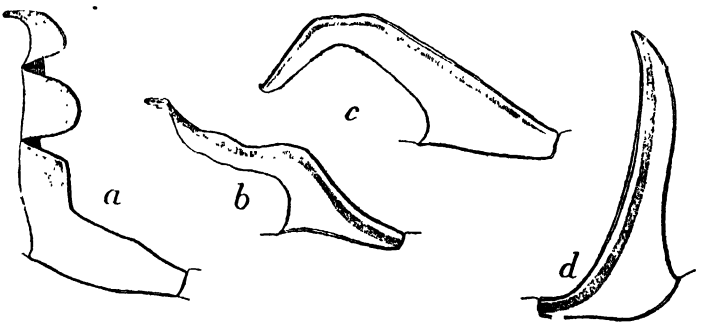


FIG. 3.—Gill-lamellæ from the middle region of the ctenidium of Viviparidæ.
a. Lecythoconcha lecythis.
b. Lecythoconcha lecythis (a relatively narrow and less folded type).
c. Lecythoconcha chinensis f. *catayensis*
d. Margarya melanoides.

present. With regard to the latter feature *L. lecythis* and *L. chinensis* f *catayensis* come very close. They have about thirty more or less

[1] Dr. Annandale has observed that males of this species are considerably less abundant than females in the Loktak Lake, Manipur valley.

equal-sized embryos without bands on the shells. In *L. sclateri* however, there are only five full-grown embryos, which have three rows of chaetae on the shell but no bands. Eggs with undeveloped or partially developed embryos in the uterus are very few and the uterus is often without them.

Margarya Nevill.

The collection contains only one specimen of *Margarya melanoides* Nevill in spirit, which is badly damaged and consequently no observations on the soft parts except the gill-lamella and the brain could be made.[1]

The relationship of the genus to other genera of Viviparidae with regard to the structure of the mantle-edge has been discussed by Annandale in his and Sewell's monograph on *Vivipara bengalensis*.

The head of the animal is small in proportion to its size. The gill-lamella is more or less straight, vertical and narrow and tapers gradually from the base towards the apex. The superior margin is thickened but never thrown into folds as in *Lecythoconcha*. Heude's figure of the gill-lamella agrees more or less closely in outline with the one figured here, but the natural position of the lamella could not be made out in the specimen examined by me. The ganglia and commissures of the brain are much larger and stouter than in species of *Lecythoconcha*. The form and sculpture of the embryonic shell is quite distinct from those of other genera of Viviparids. The number of embryos found in the uterus is unknown.

Reviewing the family as a whole it is clear that while it stands distinct from the closely allied freshwater families in its viviparity and in the structure of the male organ, the genera are distinguished chiefly by the sculpture of the shell, the variety in which is due to very slight differences in the structure of the mantle edge. The statement made by Annandale and Sewell as to its anatomical homogeneity is fully justified. There are, however, certain generic characters in the soft parts, though shell-sculpture is the main generic character.

The specific differences are subtle and exist both in the general form of the shell and in the soft parts.

The following synopsis gives the main generic differences in the soft parts of the genera examined :—

a. Edge of mantle greatly thickened with a conspicuous sphincter muscle along it Superior margin of gill-lamella usually thrown into folds ... ... *Lecythoconcha*.

b. Edge of mantle not so thickened and without a conspicuous sphincter. Superior margin of gill-lamella never thrown into folds.

a[1]. Free part of gill-lamella very long with its superior margin conspicuously thickened ... ... *Margarya*.

b[1]. Free part of gill-lamella relatively short with superior margin never so conspicuously thickened.

1. Margin of mantle with enlarged and highly vascular finger shaped processes ... ... *Dactylochlamys*.

[1] Heude *op. cit.*, pl. xliii, figs. 1 and 2.

2. Margin of mantle with only minute triangular prominences.

   1. Full grown embryos in the uterus never more than four in number. Central nervous system strongly developed. Lining of stomach thrown into folds which are often chitinised and with ridge-like chitinous thickenings at the entrance to the stomach. *Taia.*

   2. Full grown embryos in the uterus as a rule more than four. Central nervous system less developed. Lining of stomach without folds or chitinous thickenings ... ... *Vivipara.*

NOTE ON A COLLECTION OF FRESHWATER GASTROPODS FROM THAZI

BY H. SRINIVASA RAO, M.A.,
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Returning from a tour in the Southern Shan States in April 1922 Dr. Sunder Lal Hora obtained a few freshwater gastropod molluscs from a stream near Thazi railway station while waiting for the train to Rangoon. Insignificant as the collection was in point of number of species and of individuals, it proved to be of some interest in elucidating some points in the systematic position of allied or closely allied species previously recorded from Burma.

The collection contains four species belonging to two families, of which one has proved to be new and another a new form of a known species from Burma.

MELANIIDÆ.

Paludomus dhuma sp. nov.

The shell is thick and of a uniform dark colour somewhat like that of smoke. It has an ovate-conical outline with the spire elongate and slightly decollate. It consists of 4 to 5 convex rapidly increasing whorls, the last being about 2/3 as high as the shell. The base of the spire in dorsal view measured at right angles to the main axis is approximately 2/3 of the maximum diameter of the body-whorl. The suture is moderately impressed and almost horizontal. The aperture is regularly oval and slightly inclined to the main axis of the shell. The columellar callus is fairly thick and smooth and extends above to meet the outer lip thus forming a triangular thickening immediately above the aperture. It extends below up to the anterior extremity of the aperture where it is slightly flattened. The outer lip is thin and sharp. In young shells three spiral bands of a brown colour are visible on the inner side of the aperture. The sculpture is very characteristic and consists of fine but distinct vertical striæ which gradually become closer and more numerous on the last whorl, and of indistinct but nearly equidistant spiral striæ which are superimposed on a ground-work of extremely fine parallel striæ which are wavy in their course. These become inconspicuous on the outer regions of the body whorl where they are obscured by the vertical striæ. In addition to the indistinct spiral striæ, there are constantly present three well marked striæ, better seen in some than in others, running close to the suture Lines of growth are often prominent. In partly worn-out shells the sculpture is somewhat more distinctly visible.

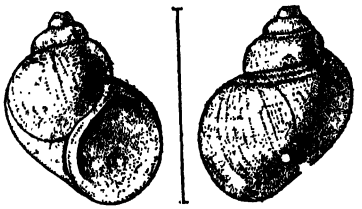


FIG. 1. – Type-specimen of *Paludomus dhuma* sp. nov.

Measurements in millimeters.

	Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.	Number of whorls in the spire.
1 (Type specimen.)	24·0	14·0	17·5	9·0	3
2	22·0	13·7	16·0	8·5	4
3	21·5	16·0	15·6	8·0	2½
4	26·2	16·2	20·0	10·5	...

Measurements of No. 4 refer to a large specimen taken by Captain F. W. Walker in the Meiktila Lake, Upper Burma.

Type-specimen.—No. M. 12485/2, Zool. Surv. Ind. (*Ind. Mus.*).

Three shells were collected by Dr. Hora from the edge of a stream near Thazi railway station, Lower Burma. A number of shells collected by Captain F. W. Walker of the Geological Survey of India, at Halin, Burma, in April 1922 belongs to the race *peguensis* of *P. andersoniana*. The deep colour of the shells and the incised spiral lines serve to distinguish them from those of the new species at a glance. The shells from Kin-U in the Chindwin valley, Upper Burma, which were described by Annandale as *Temnotaia incisa*[1] really belong to *Paludomus*.

The species is closely allied to *P. andersoniana* Nevill especially to the race *peguensis*, but differs in having a relatively short spire and a characteristic sculpture and colour.

Acrostoma reevei f. **olivacea,** nov.

Shells of this form approach those of *A. reevei* var *lanceolata* Nevill but differ in having less tumid whorls in the less strongly impressed

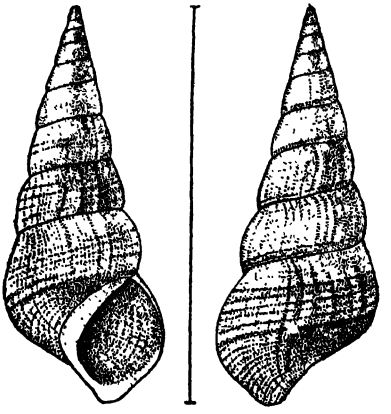


Fig. 2.—Shell of *Acrostoma reevei* f. *olivacea*, nov.



Fig. 3.—Operculum of same.

[1] Annandale, *Rec. Ind. Mus.*, XIX, p. 115 (1920).

suture, in the spiral sculpture consisting of fine parallel ridges (instead of impressed striæ) which become more prominent on the last three whorls, in having fine close-set vertical striæ which often form minute varices on the last whorl, in the aperture being a little more compressed, its columellar side being less arched, in the less strongly developed columella, and in their dull olivaceous colour. The upper whorls are often dark while the rest of the shell is olivaceous.

In some shells the columellar fold is reflected outwards as a more or less broad flap leaving a narrow channel running down the umbilicus.

The operculum is strongly chitinous, ovate-conical in outline, and paucispiral. In the specimens examined the operculum was split up along the lines of the paucispiral.

The radular teeth approach those of *A. variabilis* but have distinct features especially in the central which has three cusps on each side of the median and in the marginal which has the broad rectangular chitinous flap from the outer side of the middle region of the tooth.

The young shell is very similar to that of var. *lanceolata* but differs in having a more prominent sculpture.

In two shells examined remains of the animal were detected and carefully removed by treatment with caustic potash. They were then washed in water and left in a mixture of glycerine and 70 per cent alcohol. On dissection it was found that several embryos, not exceeding 3 mm. in height and 2 mm. in breadth were closely packed in what was apparently a brood-chamber immediately behind the head of the animal. As the specimens were very much crumpled owing to bad preservation the exact relationship of the brood-chamber to the genitalia could not be made out by dissection. Our knowledge of the anatomy of Indian Melaniids is very meagre and so far as I am aware there is no record of viviparity in the Indian species of the family, though in Europe viviparous species are known among the Melaniidæ.[1]

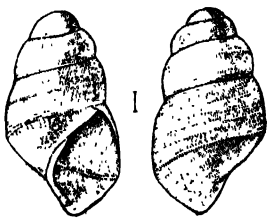


Fig. 4.—Embryonic shell of *Acrostoma reevei* f. *olivacea*.

In one of the two specimens dissected the edge of the mantle and a portion of the rectum were in a good condition. The former bore no processes and had a regular and sharp outline. In the latter were found bundles of elongated rod-like fæcal pellets consisting of fine mud. The individual pellets were apparently bound together by some sticky secretion from the rectum.

The embryonic shells are somewhat transparent and have about four complete whorls, the apical being broad and blunt. The whorls of the spire appear to be telescoped and are separated by a fairly deep suture. The spiral sculpture consisting of fine ridges is well developed especially on the last whorl and in the middle region of the remaining whorls. The operculum is very thin and transparent and exactly fits the mouth of the shell. It is slightly depressed in the middle.

Dr. Hora obtained a few specimens of this form from the Thazi stream. The shells collected by Captain F. W. Walker in Meiktila Lake,

[1] Pelseneer in Lankester's *Treatise on Zoology*, Part V, p 131 (1906). The only reference to an Indian species I have been able to trace is a description of the animal of *Melania* by Benson in *Gleanings in Science*, II, p 20 (Calcutta 1830).

Upper Burma, also belong to this form. The largest specimen in our collection has the following measurements in millimeters :

Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.
56·5	17·5	21·0	11·0

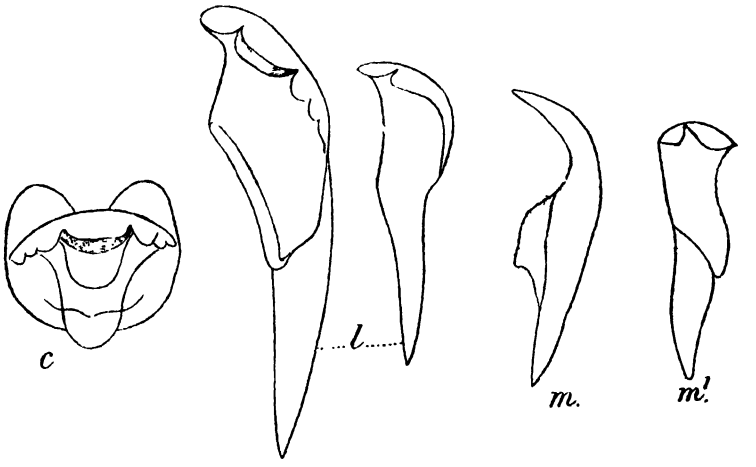


FIG. 5. Radular teeth of *Acrostoma reevei* f. *oliracea*. *c*. central : l. lateral ; *m m*¹. side and front views of marginal.

VIVIPARIDÆ.

Vivipara bengalensis race **doliaris** (Gould).

1921. *Viripara bengalensis* race *doliaris*, Annandale, *Rec. Ind. Mus.*, XXII, p. 273, pl. i, fig 9.

Two shells of this race were obtained by Dr. Hora near the Thazi stream. They are apparently young specimens of this race. The biangulate outline of the body whorl is not at all conspicuous. One of the shells is partly worn out and somewhat thicker than the other.

Vivipara dissimilis var **decussatula** (Blanford).

1854. *Paludina dissimilis* subvar. *decussatula* Nevil, *Hand List Moll.* II, p. 30.

Dr. Hora found two shells of this form on the banks of the Thazi stream. One of them is fairly fresh, while the other is more or less worn out and slightly decollate. They agree closely with the Burmese specimens of this form in the collection of the Indian Museum, but have their spire relatively short. This form apparently forms a link between *V. dissimilis* and the smooth-shelled species of *Lissotaia*, a new subgenus of the Burmese *Taia* proposed recently by the late Dr. Annandale and myself.[1]

[1] Annandale and Rao, *Rec. Ind. Mus.*, XXVII, p. 120 (1925).

ASIATIC SUCCINEIDAE IN THE INDIAN MUSEUM

By H. Srinivasa Rao, M.A.

Officiating Assistant Superintendent, Zoological Survey of India.

(Plate XXVIII.)

The distinguished French malacologist Morelet wrote as follows of the Succineidae : " Les animaux sont plus variés dans cette famille que leurs coquilles, et peutre fourniraient-ils de meilleurs caractárs sice moyen d'appreciation ètait á la portèe des naturalistes. "

With this statement my own observations are in full agreement and in the following notes I have discussed in detail only those species in which the radula as well as the shell is available for study, or those in which the shell is very distinct. I have also included short notes on other species in the collection of which the anatomy is not known.

In dealing with the Indian species in the collection I have had the advantage of studying some amount of material from Europe and America accumulated in the collection by workers on Indian malacology. But the European forms are unfortunately in a much worse state of confusion than the Indian material as regards their mutual relationships. Until recently the mere collection of shells and their naming without reference to the soft parts or the habits of the animals have been the recognized methods of studying this group, with the result that our knowledge of these animals is as incomplete as ever before.

So far as I am aware zoological literature does not furnish a single instance of a complete account of any one European species, at least as regards those systems of organs which are most likely to be useful for taxonomic purposes.

Deshayes[1], in 1831, first gave a short account of the anatomy of *Succinea putris* (Linn.) = *Helix putris* Linn. In 1912 Rieper[2] described the reproductive system of *Succinea* more or less completely, giving a brief review of anatomical work done, chiefly on the genitalia, since Deshayes's time. A systematic study of the jaw and radula in addition to the genitalia was never attempted except in the case of a few species. Baudon[3] put the then known species of *Succinea* under three groups according to the texture of the jaw. He was followed by Hazay[4] in 1880 who erected four groups with reference to the texture, colour and shape of the jaw in various species. Westerlund[5] gave a more complete account of these groups, including all the known species and varieties under the four sub-genera *Neristoma* Klein, *Amphibina* (Hartm.), *Lucena* Oken, *Oxyloma* Westerl., all based on characters in the jaw.

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[1] Deshayes, *Ann. Sci. Nat.*, XXII, p. 345, pl. ix (1831).
[2] Rieper, *Ann. Soc. Roy. Malac. Belgique*, XLVII, p. 125, pls. iii–iv (1912).
[3] Baudon, *Journ. Conchyliol.*, XXV, p. 128, pls. vi—x (1877).
[4] Hazay, *Malakozool. Blätt.*, III, p. 43, pls. iii—ix (1880).
[5] Westerlund, *Fauna Palæarktischen. Binnenconch.*, V, pp. 1—17 (1885).

As regards the radula there are practically no European references except one in Lehmann's *Die lebenden Schnecken und Muscheln* (1873). The American species of this family have, however, received better treatment in this respect, chiefly at the hands of Bland and Binney[1], whose monograph on the Land and Fresh-water shells of North America is well-known.

The Asiatic species, like the European, have been mostly established on shell characters, but there is less confusion as regards their mutual relationship owing to the fact that several of them bear distinctive characters in the shell as well as in the soft parts.

Outside Indian limits, the anatomy of the Japanese *Succinea horticola* Reinhardt has been described by Jacobi[2]. Before 1918 the only Indian species of which anything was known about the soft parts were *Camptonyx theobaldi* and *Lithotis rupicola*, two rare species restricted to Western India.

In fact the literature on Indian Succineidæ is very scanty, and it seems that far less attention has been paid to this family than to the aquatic groups of the Pulmonata. The late Dr. Annandale, who for some years before his death had been working on the Indian fresh-water gastropods, laid stress on the indispensability of anatomy and bionomics in taxonomic work. This fact was, however, never impressed on the earlier malacologists who worked in India on fresh-water molluscs, although Stoliczka and latterly Blanford and Godwin-Austen were convinced of the importance of anatomical characters in the land-snails. We thus owe our present confusion in this family to the all-too-brief descriptions of species based on a single or a few old and discoloured shells, to the inadequacy of accurate figures, and to the almost total absence of observations on the anatomy and habits of the animals.

In 1918 Annandale[3], in his report on the Fauna of the Inlè Lake, gave a short account of the habits of *Succinea indica* Pfeiffer with figures of the shell, jaw and radula. He was followed by Amin-ud-Din[4] who published a more or less complete account of the anatomy and habits of four Indian species. From his account it seems clear that the jaw, radula and genitalia afford important characters for the classification of the species.

The present account is admittedly incomplete owing to the fact that several of the species in our collection are represented by dry shells, with the remains of the animal only in a few cases. From these I have been able to extract the jaw and the radula, which are here figured. There are other species recorded from Calcutta which I have been unable to rediscover, perhaps owing to the fact that they are cryptic in their habits. I have placed together as many facts as I could gather from previous accounts, in addition to my own observations on the anatomy and habits of the group.

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[1] The works of these authors have been published jointly and individually in the volumes of the *Amer. Journ. Conch.* and in *Ann. Lyc. Nat. Hist.*, New York.

[2] Jacobi, *Journ. Coll. Sci. Tokyo*, XII, p. 82, pl. vi, figs. 116—119.

[3] Annandale, *Rec. Ind. Mus.*, XIV, p. 105, pl. x, figs. 10-11 ; pl. xi, figs. 5-6 (1918).

[4] Amin-ud-din, *Rec. Ind. Mus.*, XXII, p. 592, text-figs. 20—28 (1921).

The late Dr. Annandale gave me invaluable suggestions in the course of this work. My thanks are due to Dr. B. Prashad for going through the proof with me.

The Indian Succineidae comprise four distinct genera *Succinea* Draparnaud, *Indosuccinea* gen. nov., *Lithotis* Blanford, and *Camptonyx* Benson, each of which has distinguishing features in the shell and also in the soft parts so far as they are known. The genus *Camptoceras*, about the systematic position of which there has been much confusion, was rightly referred to the family Planorbidae by Walker[1]; and Annandale and Prashad[2], after a careful examination of the jaw, radula and penis-sheath of the Indian species, have confirmed Walker's view.

The genus *Camptonyx* was established by Benson on the peculiar form and texture of the shell, but he was doubtful about its true relationship, though he suggested it might eventually be referred to the Helicidae or the Ancylidae, or might prove to be the type of a new family. None of his surmises proved correct. Woodward[3], who examined the animal in more detail, did not express a definite view about its affinities. Gray[4], curiously enough, thought that the genus was closely allied to the genus *Otina* from a similarity of habits and external features, and even suggested the inclusion of the two genera under the family Otinidae. But the habits of the two genera, even according to his description and reasoning, are not so similar as he seems to make out.

From the description of its habitat by Theobald, who first discovered the type-species, and from a careful comparison of its jaw and radula with those of the species of the other genera, it is clear that *Camptonyx* belongs to the Succineidae. The other three genera also are undoubtedly to be included in this family.

The members of this family may be recognized by the following characters:

Shell.—Imperforate, usually oval, rarely cap-like, relatively thin and translucent, never smooth, but rarely with prominent sculpture; spire much shorter than the last whorl, never sharply conical, whorls rapidly increasing; aperture oval or oblong, with a thin columellar fold not reflexed beyond the columellar margin of the aperture.

Alimentary system.—The jaw is chitinous, and consists of an anterior cutting piece, which may be variable in shape and texture, and a broad accessory plate behind it, also variable in form and texture. The radula is very variable both in size and form of the teeth, and in the number of teeth in each transverse row. The central is usually a conical tooth with or without lateral denticles. The laterals have, as a rule, only two cusps, while the marginals may have two to seven. The alimentary canal is fairly long with the stomach and greater part of the intestine in the visceral hump. A short oesophagus leads to a spacious crop which communicates with the stomach. A pair of compact salivary glands with short ducts is present. A pair of caeca opens at the junction of the stomach and the intestine. The intestine lies coiled

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[1] Walker, *Occ. Papers Mus. Zool. Univ. Michigan*, No. 64, pp. 1–6, pl. i (1919).
[2] Annandale and Prashad, *Journ. Asiat. Soc. Bengal*, N.S., XVI, p. 30 (1920).
[3] Woodward (in Benson), *Ann. Mag. Nat. Hist.*, 3rd Ser., I, p. 338 (1858).
[4] Gray, *Ann. Mag. Nat. Hist.*, 3rd Ser., I, p. 406 (1858).

over the stomach. The rectum is short and leads to the slit-like anus on the right side of the pulmonary chamber.

Respiratory system.—The pulmonary chamber occupies the anterior portion of the body-whorl and communicates with the outside by a minute rounded aperture anterior to the anal slit, and has a thin membranous roof.

Kidney.—This organ is a rectangular, usually yellowish body forming the posterior boundary of the pulmonary chamber.

Genitalia.—These consist of a compact hermaphrodite gland occupying the apex of the spire, a convoluted duct into the distal half of which open two to three seminal vesicles, and which divides into male and female ducts below the level of the albumen gland. The spermatheca, the prostate, the uterus and the penis are variable in form and size. The penis has a single retractor muscle. The male and female openings may be separate or united, but are always close together on the right side of the base of the head.

The following key will help the identification of the Indian genera from shells only :—

A. Amphibious Succineidae with shell of very variable size, shape and texture ; columellar fold thin, with a distinct smooth ridge ... ... *Succinea.*

B. Terrestrial Succineidae usually with a thin shell ; columellar fold without a smooth ridge.

1. Shell with a transverse furrow on the inner surface of the upper part of the body whorl.

   a. Shell thin, cap-like, with the whorls of the spire loosely coiled ; columellar fold very thin ; aperture oblong or rounded, at any rate in the adult ... ... *Camptonyx.*

   b. Shell somewhat thick, ovate ; spire short and depressed with the tumid whorls tightly coiled, suture impressed ; columellar fold relatively broad ; aperture ovate ... ... *Lithotis.*

2. Shell without a transverse furrow, very thin and fragile, elongate-ovate ; spire short without impressed suture ; cellumellar fold thin and minute ... ... *Indosuccinea.*

TERRESTRIAL SUCCINEIDAE.

Camptonyx Benson.

The affinities of this genus to the other genera in the family have been briefly discussed above. The form and texture of the shell are very distinct. This genus is represented in the collection by the type-species *Camptonyx theobaldi* Benson.

Camptonyx theobaldi Benson.

1858. *Camptonyx theobaldi*, Benson, *Ann. Mag. Nat. Hist.*, Ser. 3, I, p. 336, pl. xii.
1876. *Camptonyx theobaldi*, Hanley and Theobald, *Conch. Ind.*, p 35, pl. 81. figs. 5, 6.

This species is represented in the collection by three shells from the Girnar Hills, Kathiawar. Nevill records thirteen shells from the same

locality ; all but three apparently having been lost or given away. One of the shells has a tough strip of epiphragm attached to part of the margin.

Measurements in millimeters.

Height of shell.	Height of aperture.	Breadth of aperture.
5·5	5·0	4·6

I have extracted the jaw and radula from one of the three shells, but they do not quite agree with Woodward's figures. In my preparation of the jaw the anterior margin of the cutting piece bears no median process, and the cutting piece is a triangular structure with its apex directed backwards, and the apices of the very short arms rounded. There is a shallow median depression on the anterior margin. The sides of the basal plate are depressed. These structures are apparently subject to great variability.

In the radula the teeth are very small and do not exceed 65 in number in each transverse row. The basal plate of individual teeth is always higher than the cusps. The central is without lateral projections but has two depressions on the sides just below the cusp. The laterals have two cusps, the ectocone gradually increasing in size from within outwards. The marginals have 3 to 7 cusps of which the entocone is the largest. The approximate radular formula is 16·14·1·14·16. Though Woodward has figured the same number of teeth in one half of a transverse row as I have done, there is no essential agreement between the two figures. In his figure the central is much sharper and is without lateral depressions, and the laterals have only one cusp while the marginals have two. These striking differences in the jaw and radula seem to be sufficient to regard the shells in our collection as representing a new form of *C. theobaldi*, but for want of sufficient material to study the extent of variation I refrain from regarding these shells as distinct.

Lithotis Blanford.

This genus is represented in the collection by the type-species *L. rupicola* Blanford, and by *L. tumida* Blf. It is very distinct from *Succinea* in shell characters and is distinguished by the short depressed spire with the whorls not closely coiled, by the characteristic coarse sculpture, the broadly oval aperture, the well-defined relatively thick columellar fold continuous with the outer margin of the aperture above, and by the presence of an internal furrow commencing from about the middle of the outer margin and running transversely across the upper part of the last two whorls.

The jaw and radula have no characteristic features and agree with those found in the genus *Succinea*.

Nothing is known about the genitalia or other organs.

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[1] As very little is known about the anatomy of these animals it is difficult to say anything about the formation or function of the furrow, though Blanford observes that it may be a siphonal furrow. Such a furrow is not uncommon in terrestrial gastropods, as for instance in the genus *Cataulus* (Cyclophoridae), but is never extended up to the spire as in *Lithotis*.

Lithotis rupicola Blanford.[1]

1863. *Succinea* (*Lithotis*) *rupicola*, Blanford, *Ann. Mag. Nat. Hist.*, Ser. 3, XII, p. 186, pl. iv, figs. 8–10.
1874. *Lithotis rupicola*, Binney, *Proc. Acad. Nat. Sci. Philadelphia*, pl. v, figs. 3–6.
1914. *Lithotis rupicola*, Gude, *Fauna Brit. Ind. Moll. Gastro.*, p. 458.

The shells collected by Blanford himself at Khandalla in Bombay Presidency and recorded by Nevill are in the collection. There is a certain amount of variability in the depth of the internal furrow. Young shells have a much deeper furrow than adult ones. The shell of this species approaches in some respects that of *Camptonyx theobaldi*, at any rate much more than *L. tumida*[2] does.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
7·5	6·8	5·2	5·0

The jaw of this species differs from that of *L. tumida* in the greater prominence of the median projection on the cutting margin. Binney's figure of the jaw of this species is incomplete, the accessory basal plate being omitted.

The radula of *L. rupicola* appears to be intermediate in features between that of *L. tumida* and *C. theobaldi*. The teeth are relatively narrow and are shorter than the basal accessory plate, and the marginals have an elongated cusp with two small denticulations on the outer side. The radula in this respect differs from that of *L. tumida*.

Lithotis tumida Blanford.

1876. *Lithotis tumida*, Hanley and Theobald, *op. cit.*, p. 35, pl. 81, figs. 8, 9.
1878. *Succinea* (*Lithotis*) *tumida*, Nevill, *Hand List Moll.*, I, p. 214.
1914. *Lithotis tumida*, Gude, *op. cit.*, p. 459.

Shells collected by Blanford from the type-locality are still in the collection. They are all faded to a yellowish brown colour and have 2½ to 3 whorls. Though the shells approach in general form those of *Succinea* (especially a species like *S. bensoni* Pfr.) they can easily be separated from the latter by the characters mentioned under the genus.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
8·0	5·5	5·5	4·3

I have been able to extract the jaw and radula from the dried animal in one of the shells. The jaw is roughly a square with the cutting piece broad. The arms of the latter are almost horizontal and obtusely rounded

[1] I have since been able to study the anatomy of this species more completely from a large number of well-preserved specimens collected by Dr. S. L. Hora at Khandalla. (*Vide* Rao, *Rec. Ind. Mus.* XXVII, pp. 387–394, 1925.)

[2] Preston's *Lithotis japonica* from Lake Biwa is not a *Lithotis*, nor does it belong to the Succineidae. Annandale and Prashad (*Journ. As. Soc. Bengal*, N.S. XIV, p. 460, fig. 2, pl. xii, figs. 4, 5) have accepted it as the type of their genus *Omia* of the family Limnaeidae.

at the apices. The anterior margin is raised into a median and two lateral convexities. The basal accessory plate narrows from behind forwards and has its posterior margin nearly straight.

There are about 40 radular teeth in each transverse row, the laterals and marginals being hardly distinguishable from one another. With the exception of 2 or 3 of the last marginals the teeth have uniformly two cusps. The right side of the radula exhibits some abnormalities while the left is normal. The cusps of the teeth are elongated, sharp and conical. The central has a median broad conical cusp with lateral projections. The approximate radular formula is 20·1·20.

Indosuccinea, gen. nov.

The type-species of the genus was hitherto considered to be a *Succinea*. Amin-ud-din in dealing with the Manipur Succineas (*op. cit.* p. 593) placed this in a biological group distinct from that of the amphibious species, and also pointed out the differences in the anatomy of the members of the two groups. On a re-examination of the same material I find that the shell and the soft parts are sufficiently distinct, and that the erection of a distinct genus is necessary for the reception of this species.

The shell is relatively large, thin and fragile, and has a coarse sculpture with oblique striae. The spire is very short when compared to the body-whorl, tumid, and consists of 1½ to 2 whorls, the apical being minute. The suture is not impressed. The aperture is large, oval, pointed above and slightly inflexed near the lower end of the columellar fold. The columellar fold is thin and minute. The colour of the shell varies from amber to pale-yellow. The jaw is very strongly chitinised, broader than long, with the apical portion of the arms curved in the form of a beak. The centre of the anterior margin is as a rule straight, but may also be raised into minute prominences. The basal accessory plate has nearly straight sides and a concavity in the middle of its posterior margin.

The radular teeth are much more numerous than in *Succinea* and the central has a conical median and two accessory lateral cusps.

The roof of the pulmonary chamber is highly vascular and has well-defined branching blood-vessels.

The genitalia are remarkably different from those of any known species of *Succinea*. There are two stout, oval seminal vesicles with a distinct fecundation pouch. The prostate has a spiral torsion, and the vas deferens is short, opening into the more or less bulbous penis which has no retractor muscle. The ducts of the spermatheca, vagina and the penis have separate external openings, but they all open to the outside in a common slit-like aperture on the right anterior side of the body just below the tentacle.

Thus the very fragile nature of the shell, its characteristic shape, the highly vascular lung, the strongly chitinised jaw with beak-like extremities to the arms, the large number of marginals in the radula, and in the genitalia the spiral torsion of the prostate, the very short vas deferens with a small bulbous penis devoid of a retractor muscle, the spermathecal duct having a separate external opening instead of being connected with the vagina, and above all the terrestrial habit are the distinctive characters of the proposed new genus.

Type-species.—*Indosuccinea semiserica* (Gould).

Distribution of the genus.—The type-species occurs only in Bengal and Burma, but there seem to be some closely allied forms, which probably extend the range of the genus into Indo-China and the Malay Peninsula.

Indosuccinea semiserica (Gould).

1876. *Succinea semiserica*, Hanley and Theobald, *op. cit.*, p. 29, pl. 67, figs. 2, 3.
1878. *Succinea baconi*, Nevill, *op. cit.*, p. 214.
1914. *Succinea semiserica*, Gude, *op. cit.*, p. 452.
1921. *Succinea semiserica*, Amin-ud-din. *Rec. Ind. Mus.*, XXII, pp. 592—600, figs. 21 (3*a* and 3*b*), 26 and 27.

Our collection contains shells from the west and south of Burma, from the Mergui Is. and from Serampore, Calcutta and Chittagong in Bengal. There is also a good collection of preserved material from Rangoon taken by Dr. H. H. Marshall. The shells from Mergui are relatively small and thick and have the upper part of the body-whorl more tumid. The series from Burma are by far the largest in size. They are fragile and vary in colour from amber to pale-yellow or white according to the condition of their preservation.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
18·0	15·0	9·2	8·8

I refer to this species a single broken shell from Calcutta labelled *Succinea baconi* Pfr. It does not agree with Hanley and Theobald's figure of *S. baconi*. It, however, closely resembles one of the two shells from Chittagong which has a very short spire and a tumid body-whorl.

Succinea cochin-chinensis Pfr. which is found in our collection is probably no more than a form of *I. semiserica*.[1] It has a shorter spire and a relatively broad aperture, but in other respects it is very similar to the latter species. The anatomy is unknown. *I. semiserica*, which is widely distributed in Burma, extends its range probably into Siam on the east and the Malay Peninsula on the south.

Anatomy.—The jaw is, as a rule, strongly chitinised, especially the cutting piece. The extremities of its arms are somewhat thick, dark, beak-like, and project backwards and inwards. The cutting piece is about as broad as the basal accessory plate and has its free margin deeply concave, while the middle portion of this margin at the bottom of the concavity is subject to some variability. It is usually a straight edge with very minute denticulations, but may also be raised into a median and two lateral prominences. The free margin when extremely worn out appears indented. It is often normal. The basal accessory plate has almost parallel sides while its posterior margin is concave in the middle.

In the preparation of the jaw in the members of this family it is customary to use caustic potash for extracting it. While caustic potash

[1] Morelet, *Series Conchyliol.* p. 243, pl. xii, fig. 4 (1875).

certainly clears the muscle fibres attached to the jaw, it also seems to have some action on the delicate portions of chitin so that jaws prepared in this way do not retain their exact outline. As the form of the jaw is so important for specific differentiation, material should not be boiled too long in the caustic potash. Where the jaw is delicate the head of the animal may be allowed to soak in cold caustic potash for 12 to 24 hours, and then cleaned in water. The outline of the jaw is thus properly preserved. In fairly large forms as in *I. semiserica* the jaw may be cleared of its muscle fibres by soaking it in water and cleaned by means of a lancet and a needle.

The radula is a relatively broad ribbon with approximately 80 to 90 marginals, which is nearly twice the number found in any species of the genus *Succinea*.

Amin-ud-din's figure of the radular teeth does not appear to be quite accurate. I have examined his own preparations of the radula, and some of mine. His figures do not agree with either of them. The central and laterals of this species are very characteristic and differ from those of the species of *Succinea*. The central has a broad heart-shaped median tooth and a small lateral tooth on each side. In one preparation the central was very much reduced. This is apparently an abnormality which is not uncommon in whole longitudinal rows of certain radulae. The same phenomenon is probably widespread in other groups of the Pulmonata. In the Limnaeidae and Planorbidae, for instance, such abnormalities are common.

The laterals are less than ten in number and have their entocones usually broad and roughly dagger-shaped. The first few laterals have often two cusps while the remaining have 3 or 4 cusps, but the former may also have three cusps. The change from laterals to marginals in a transverse row is gradual, but the first few marginals can often be easily marked out by their sharp and narrow entocones. The marginals are aculeate in form and vary from 80 to 90 in number. There are, as a rule, four cusps, the entocone being the largest. The two middle cusps are sub-equal and smaller than the fourth.

The pulmonary chamber is large and has its dorsal wall thin and translucent. Patches of dark pigment may or may not be present on the external surface of the dorsal wall. The distinction drawn by Amin-ud-din between this species and those of the amphibious group in the translucence of the lung of one and the opaqueness in the others does not seem to be quite sound, for black pigment is present on the dorsal surface of the lung in species of both groups and is liable to disappear in equal degree in both. The more important distinction between *Indosuccinea* and *Succinea* would, however, be the very highly vascular nature of the lung in the former where thick branching vessels may be seen, and the minuteness of the vessels in the latter.

The kidney is relatively narrow and extends along the whole length of the posterior side of the lung. Calcareous concretions are present in the substance of the kidney in much smaller quantities than in some species of *Succinea*. Individuals of this species were taken between July and September, *i.e.*, during the rainy season in Burma. In certain species of *Succinea* taken during the cold weather in other parts of India these calcareous concretions have been found in great abundance. The free deposition of the particles is probably a result of low temperature of the atmosphere.

The genitalia have already been dealt with in the definition of the genus, but one more point remains to be stated. There are two stout ovate seminal vesicles (sometimes unequal in size) which open into two somewhat dilated tubes with which the hermaphrodite duct joins just before they enter the prostate. There is also a third narrow, compressed, thick-walled tube shorter than the seminal vesicles which also joins the ducts of the latter. This tube, presumably, corresponds to the fecundation pouch, which, in *Succinea putris*, is an enlarged sac below the seminal vesicles. There is no mention of this structure in Amin-ud-din's account of this species. It is also to be found more distinctly in another species to be described hereafter.

Indosuccinea semiserica f. sthulasiras[1], nov.

This is a very delicate and small form of *I. semiserica*. The anatomy is exactly similar to that of the latter, but the shell has some distinct features. It seems advisable to regard it as a closely allied form. The shell is very thin and pliable and is of a dull amber colour and slightly shining. Its general outline is similar to that of *I. semiserica* but its spire and body-whorl are relatively tumid. The apex of the spire is very minute. The sculpture consists of conspicuous striae rather unevenly spaced. The most distinguishing feature of this form is the slight thickening of the shell in the spire and the upper part of the body-whorl. In life, the thickened portion is covered by a black deposit which when cleaned leaves a well-defined whitish, rough area.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
8·5	7·0	5·9	4·0

Type-specimen.—No. M $\frac{12370}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Several living individuals were taken by me on the leaves of a hedge-plant (*Lawsonia alba* ?) in Ballygunge, Calcutta, in July 1923.

Professor Meggitt of the Rangoon University has since found several living specimens of this form in the vicinity of Rangoon. The thickened portion of his shells is less extensive and the black deposit less conspicuous.

Indosuccinea plicata (Blanford).

1876. *Succinea plicata*, Hanley and Theobald, *op. cit.*, p. 29, pl. 67, fig. 8.
1878. *Succinea semiserica*, Nevill, *op. cit.*, p. 212.
1914. *Succinea plicata*, Gude, *op. cit.*, p. 448.

The shell of this species resembles that of *I. semiserica* in many respects, but differs from it in having a larger spire, in being relatively narrow, in having a characteristic coarse sculpture, and in being less fragile. Two shells from Arakan are typical and show the plications which distinguish this species from *I. semiserica*. The colour is variable. Shells from Bassein are pale yellow, while those from Tongoop in

[1] Derived from two Sanskrit words *Sthula* (=thick), and *Siras* (=head).

Arakan are corneous. Some of these have a white deposit of calcareous matter on the inside of the shell.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
19	16·5	11·0	9·0

The anatomy of the species is not known. From its great resemblance to the shell of *I. semiserica* it may be presumed that the anatomy is similar. The inclusion of this species in the genus *Indosuccinea* is, therefore, only provisional.

The species has been hitherto recorded only from Lower Burma, and has apparently a local distribution in that province like the closely allied I. *semiserica*.

AMPHIBIOUS SUCCINEIDAE.

Succinea Draparnaud.

This genus includes a large number of species of amphibious habitat, with shell of very variable size, shape and texture. The columellar fold is thin and has a distinct smooth ridge on its free margin. The radular teeth vary in number in different species and may be aculeate or quadrate in form. It is interesting in this connection to note that the species of *Succinea* seem to fall into two natural groups according as the marginals in the radulae are aculeate or quadrate in form. Those of which I have examined the radulae may be grouped as follows :—

GROUP I. (Species with aculeate marginals.)	Intermediate.	GROUP II. (Species with quadrate marginals).
* *S. pfeifferi* var. *recta* Baudon.		*S. bensoni* Pfeiffer.
* *S. putris* var. *propinqua* Baudon.		*S. subgranosa* Pfeiffer.
* *S. debilis* Pfeiffer.	*S. girnarica* Theobald.	*S. rutilans* Blanford.
S. yarkandensis Nevill.		*S. gravelyi*, sp. nov.
S. elegantior Annandale.		*S. stoliczkae*, sp. nov.
S. indica Pfeiffer.		*S. godivariana* f. *vangiya*, nov.
S. martensiana Nevill		*S. crassinuclea* f. *vitrea* Pfeiffer.

The marginals of *S. girnarica* are somewhat peculiar in that they are intermediate between the aculeate and quadrate forms of teeth.

The shell form in these two groups also seems to be distinct. In Group I the shell is generally of an elongately ovate form with a short spire and a relatively large body-whorl, whereas in Group II it is of a broadly ovate form with tumid whorls, and of relatively small size. S. *girnarica* has, however, an exceptionally large shell.

The members of this genus differ from *I. semiserica* in the structure and arrangement of the different parts of the genitalia. The prostate is without spiral torsion and is followed by a long vas deferens which

* These species form part of the European material in our collection, but as their systematic position seems to be in doubt, I have included them here only for purposes of comparison.

terminates on an elongated penis. The latter is provided with a retractor muscle. The duct of the spermatheca opens into the vagina. The male and female ducts are united for a short distance before opening to the outside.

The following Asiatic species in the collection are included under this genus :—

1. *S. indica* Pfeiffer.
2. † *S. indica* f. *subfossilis*, nov.
3. *S. elegantior* Annandale.
4. † *S. collina* Hanley and Theobald.
5. † *S. tornadri*, sp. nov.
6. *S. girnarica* Theobald.
7. † *S. crassinuclea* Pfr.
8. *S. crassinuclea* f. *vitrea* Pfr.
9. *S. martensiana* Nevill.
10. † *S. hanleyi* Gude.
11. *S. subgranosa* Pfr.
12. *S. bensoni* Pfr.
13. † *S. ceylanica* Pfr.
14. † *S. daucina* Pfr.
15. † *S. daucina* f. *hraswasikhara*, nov.
16. † *S. snigdha*, sp. nov.
17. *S. stoliczkae*, sp. nov.
18. *S. graveyli*, sp. nov.
19. † *S. gravelyi* f. *deccanensis*, nov.
20. *S. gravelyi* f. *andamanensis*, nov.
21. *S. rutilans* Blanford.
22. *S. godivariana* Gude.
23. *S. godivariana* f. *vangiya*, nov.
24. † *S. limnaeiformis*, sp. nov.

† Those of which the anatomy is unknown are marked thus.

Succinea indica Pfeiffer.

1914. *Succinea indica*, Gude, *op. cit.*, p. 447.
1918. *Succinea indica*, Annandale, *Rec. Ind. Mus.*, XIV, p 105, pl. x, figs 10, 11, pl. xi, figs. 5, 6.
1921. *Succinea indica*, Amin-ud-din, *op. cit.*, p. 601, fig. 28, p. 895, fig. 21 (4).

Of all the Asiatic species dealt with in this paper the present species seems to closely resemble the European *S. Pfeifferi* Rössm. and *S. putris* Linn. and their various forms, many of which have, without any justification, been raised to specific rank by European authors only to add to the existing confusion. It seems to me probable that *S. pfeifferi* and various other closely allied species and varieties in published works are no more than forms of *S. putris* Linn. The latter species is itself subject to great variability. A reference to the series of figures of this species by Forbes and Hanley[1] will make this point clear.

Pfeiffer,[2] in his description of *S. indica*, observed that it is a form similar to *S. pfeifferi*, but held that it might be distinguished from the latter by the nature of the sculpture and the aperture. I have examined shells of both species in the collection, and also seen published figures of the same. The differences between the two species, if any, are very elusive especially owing to the great variability in size, form, texture and colour of the shells. I have extracted the jaw and radula of *S. pfeifferi*[3] from Candahar and Luchon (probably in Europe), and compared the drawings of these structures with those of *S. indica* from more than one locality. The general type of structure of the jaw and radula is the same in the two species. These structures are also subject to some variability the extent of which is difficult to determine without adequate material.

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[1] Forbes and Hanley, *Brit. Moll.*, IV. pl. cxxxi, figs. 1—5.
[2] Pfeiffer, *Monographia Helici Vivent*, III, p. 9 (1853).
[3] Lehmann, *Die Lebenden Schnecken und Muscheln*, pp. 49—57, pl. ix, fig. 13. Cassell (1873).

Most of the European species have been established on shell characters only, and so far as I could gather there is little or no account of the anatomy of these species. It is therefore difficult to understand their mutual relationships. Though the Indian Museum collection possesses shells of various species from Europe and America, they are not here dealt with owing to the difficulty of instituting correct comparisons with the Indian species which are better known in respect of their shells as well as of the soft parts.

Speaking of the external characters alone it seems clear that *S. indica* is closely related to a species like *S. putris*, allied forms of which are probably widely distributed in Europe and Asia.

The Indian Museum collection contains shells from Bhim Tal, Kashmir, Peshawar, Gurdaspur, and the Southern Shan States. This includes shells from Bhim Tal and Srinagar recorded by Nevill (*op. cit.*, p. 212). A few specimens in spirit from Peshawar and the Manipur valley collected by Dr. Annandale, and a few collected by Dr. Baini Prashad in Kashmir are also present.

When the collection is examined as a whole it is possible to distinguish two forms, the long-spired and the short-spired, but the two forms occur together in all the localities. The colour of the shell varies from a reddish amber or pink to pale yellow.

Shells from the type-locality are smaller than the type and are themselves variable in form. The spire is longer in some shells than in others. The aperture is subpyramidal while its base is evenly rounded in short-spired forms and slightly angulate on the collumellar side in long-spired ones. The latter agree with the figures of *S. indica* in *Conch. Ind.* The colour of the shells is pale yellow.

The specimens from Kashmir, Peshawar and the Punjab are more or less alike but not without the usual variability common to most fresh-water species of Pulmonates. For a proper appreciation of the variability in the shell of the present species it seems best to describe individuals from different localities separately. Shells labelled 'Kashmir' in our collection apparently come from Srinagar from where Nevill has recorded 30 specimens. They are of a pale horn colour while those from the Dal Lake in Kashmir are reddish amber. The latter also differ from the former in being relatively narrow, in the greater height of the spire, in the convexity of the penultimate and body-whorls and in the deeper and more inclined suture. The shells from Kashmir as a whole are thinner than those from Bhim Tal in the Kumaon District.

Two specimens from a settling tank in the waterworks at Peshawar have a thick shell and are pale pink in colour. They agree in form with the Dal Lake specimens. Shells from Pancha Tirla tank in Peshawar, though small in size, have an elongated spire and a more tumid body-whorl. The sculpture is less coarse than in Kashmir specimens, and the colour varies from amber to pale yellow. The Punjab specimens have a shorter spire, but otherwise agree with the Kashmir individuals.

Shells from Srinagar agree both in size and form with the figure of this species recorded by Jickeli from Alexandria in Egypt.[1] The

[1] *Nova Acta. K. Leop.. Carol. Akad.*, XXXVII, No. I, p. 167, pl. vi, fig. 11 (1874).

species being so variable I have no doubt that the Egyptian example is at best a form of *S. indica* in spite of the differences mentioned by Jickeli between the Indian and Egyptian examples.

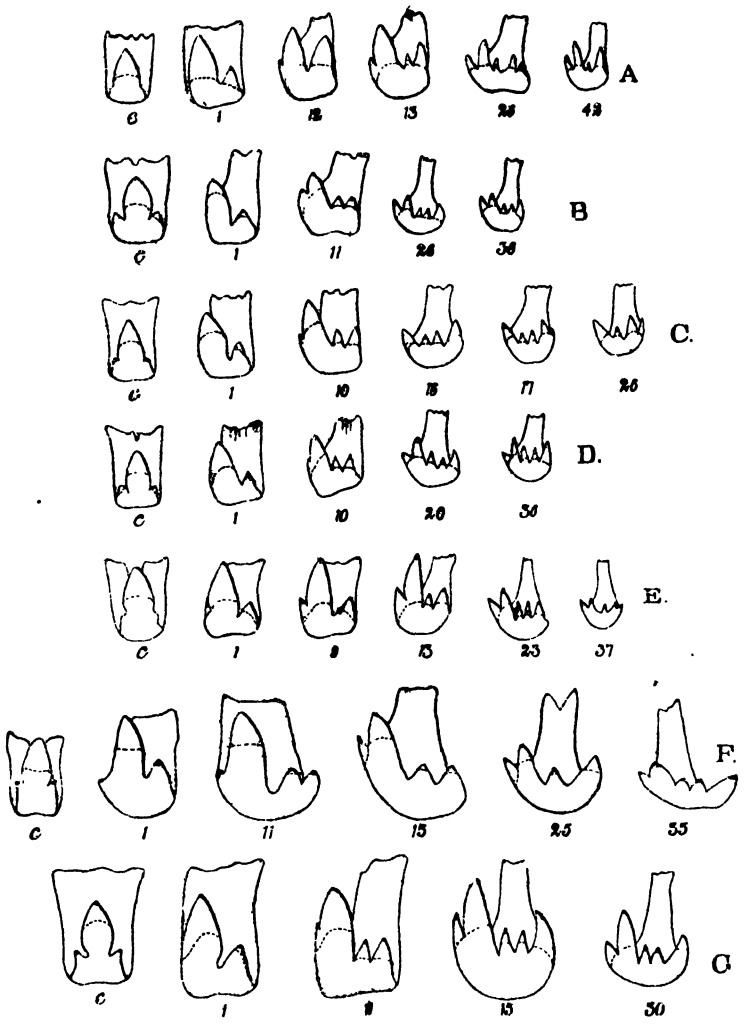


FIG. 1.—Radular teeth of Succinedae.

A. *Succinea indica* Pfeiffer from Gurdaspur, Punjab.
B. *Succinea indica* Pfeiffer from Srinagar, Kashmir.
C. *Succinea indica* Pfeiffer from Peshawar (incomplete).
D. *Succinea indica* Pfeiffer from Dal Lake, Kashmir.
E. *Succinea yarkandensis* Nevill from Yarkand.
F. *Succinea elegantior* Annandale from Manipur, Assam.
G. *Succinea debilis* Pfeiffer from Mount Hermon, Palestine.

The Burmese shells which are relatively thick and much narrower than any of the Indian examples apparently constitute a distinct race for which I propose the name *shanensis*. Among these again short and long-spired forms occur. Our collection possesses a single shell

taken by Dr. Annandale at Thali-u on the Inlè Lake and two dead shells obtained by Dr. Hora in a field at He-ho. The former has a long spire which is well marked out from the body-whorl, with the suture oblique and moderately impressed, and has a dirty yellow colour. The latter are short-spired with the suture well-impressed, and whitish in colour.

Measurements in millimeters.

Locality.	Height of shell.	Height of aperture	Greatest breadth of shell.	Greatest breadth of aperture.	Number of whorls.	Remarks.
Bhim Tal (Kumaon) ...	14·0	10·0	6·5	5·5	2½	Long-spired.
	12·5	10·0	8·5	5·5	2½	Short-spired.
Srinagar Dal Lake Kashmir ...	14·5	11·5	7·3	5·8	2½	
	13·5	10·2	6·5	5·5	2½	
Peshawar (N.W.F. Pr.) .	13·1	9·7	6·4	5·0	2½ to 2¾	
	12·2	8·5	6·2	4·5		
Gurdaspur (Punjab)	13·0	11·1	7·2	5·8	2½	
Inlè-Lake (S. Shan States)	11·1	8·2	5·8	5·0	2½ to 2¾	
He-ho (S. Shan States) ...	10·5	7·8	5·0	3·9		

The jaw and the radula, like the shell, are also subject to great variability, and the accompanying figures will indicate the degree of variability better than a mere description.

In the jaw the arms of the cutting-piece usually enclose a deep concavity and gradually broaden from behind forwards, the apex being rounded on one side. The median projection is prominent and may sometimes have accessory lateral protuberances, which probably appear as a result of wearing out of the cutting edge, or of accident. The basal accessory plate also varies greatly in shape, but is nearly always twice as broad as the distance between the anterior and posterior margins of the cutting-piece.

In the radula the central varies in size and form of the lateral denticulation. Specimens from Kashmir have prominent lateral denticulations on the central which are obsolete or sub-obsolete in those from Peshawar and the Punjab. The laterals are more or less uniform, while the marginals again show some variation.

The extent of variability in the shell, the jaw and the radula of this species seems to indicate that it is easily affected by environmental factors, such as the composition of water and the nature of the food available. But there are, presumably, other little-known factors which act on the species and bring about such frequent changes.

In the alimentary canal the stomach is large and spacious and lies at right angles to the crop. On the dorsal wall of the stomach at its junction with the intestine opens the large duct of the liver receiving

several short branches, while ventrally opens a pair of caeca. One of them is larger than the other and has oblique striations which are due, in fact, to the external appearance of the internal longitudinal folds. The smaller sac is stout, arched, and without striations. This is apparently an accessory caecum.

The kidney is broader than that of *I. semiserica* and has well developed longitudinal folds. The quantity of calcareous concretions in the substance of the kidney seems to depend upon the temperature of the atmosphere. For instance individuals taken in the month of January at Peshawar have practically no calcareous concretions in the kidney, while those collected in July at Kashmir have such large numbers of concretions that they more or less obliterate the internal folds of the kidney.

The genitalia agree somewhat with those of *S. elegantior*. The prostate is slightly more elongate than in the latter species. There is a pair of seminal vesicles opening into a fecundation pouch which sometimes carries two to three minute digitiform processes on one side. The hermaphrodite duct opens at the lower end of the pouch a little below the digitiform processes. The shape and size of the spermatheca, and the length of its duct are variable. The penis is elongate, broader distally, and carries at its apex a conspicuous finger-shaped appendix variable in size, at the base of which opens the greatly coiled lower end of the vas deferens. The penis, the appendix, and the terminal portion of the vas deferens are enclosed in a tough thin sheath which can be easily removed.

Succinea indica f. **subfossilis,** nov.

This form is closely allied to *S. indica* and has been found only in the Southern Shan States. The shell is small, elongate, and much narrower than that of *S. indica*. The spire is high and about ¼ the total height of the shell, and has two whorls, the apical being minute and papillate. The suture is oblique and well-impressed. The shell is relatively thick, coarsely sculptured, often having a plicate appearance. The aperture is narrowly elongate-ovate and has the columellar fold very thin, smooth and shining with a short minute polished ridge at its lower extremity. The colour is a pale brown or pink.

Measurements in millimeters.

Locality.	Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
Bottom of pool above He-ho gorge ...	12·0	9·0	5·8	4·8
Sand-like deposit on bank of He-ho gorge.	8·8	6·3	4·2	3·4

Type-specimen.—No. M $\frac{12372}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Comparing the dimensions of these shells with those of the living shells from the same district one finds that the sub-fossil shells are much

narrower. The present form differs from the true *S. indica* in its thicker shell, in colour, in the characteristic coarse sculpture and in its extreme narrowness.

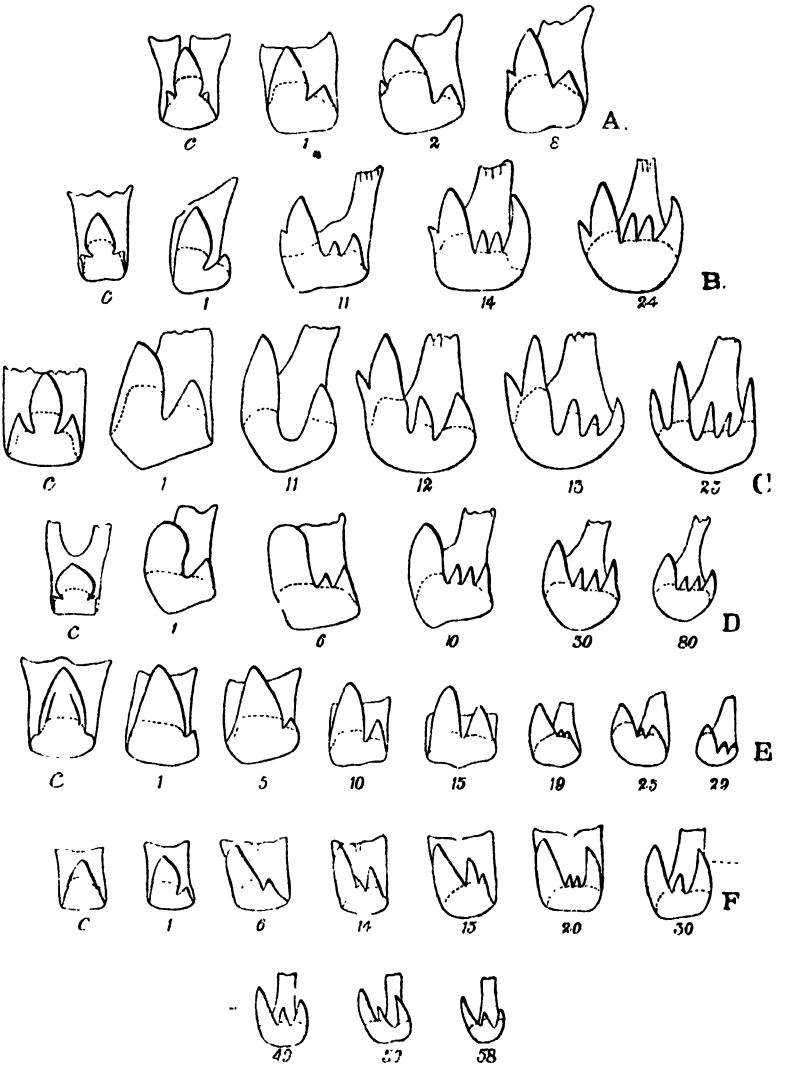


FIG. 2.—Radular teeth of Succineidae.

A. *Succinea pfeifferi* Possmässler from Candahar (incomplete).
B. *Succinea putris* var. *propinqua* Baudon from Burgos, Spain.
C. *Succinea pfeifferi* var. *recta* Baudon from Luchon, Europe.
D. *Indosuccinea semiserica* (Gould) from Rangoon.
E. *Succinea martensiana* Nevill from "Bazrahat."
F. *Succinea girnarica* Theobald from Girnar Hills, Kathiawar.

Two shells were obtained by Drs. Annandale and Gravely in March, 1917, from the bottom of a pool above He-ho gorge, and three more in

March, 1922, from a loose sand-like deposit on the banks of the same pool by Dr. Sunder Lal Hora and myself. The former are pale brown in colour and appear to be water-worn, while the latter are pink and have the sculpture well-defined.

Succinea collina Hanley and Theobald.

1876. *Succinea collina*, Hanley and Theobald, *op. cit.*, p. 30, pl. lxviii, figs 8, 9.
1878. *Succinea collina*, Nevill, *op. cit.*, p 212.
1914. *Succinea collina*, Gude, *op. cit.*, p. 449.

This species is represented in the Indian Museum by eight shells from Mahabaleshwar in Bombay and one from Torna Hills in Poona. This is one of the distinct Indian species readily recognized by its form, texture and colour. There are, however, some slight variations in the shell. The shell is of a greenish horny colour, and is covered by a thin membranous outermost layer which has a tendency to come off the underlying calcareous layer. It has a characteristic lustrous pearly layer on the inner surface of the shell.

A small shell in the series agrees more or less with the small tumid form figured by Hanley and Theobald. This is, presumably, a young shell. The single shell from Torna Hills, though slightly more tumid than the foregoing and lacking the colour and lustre of the typical shell, has the characteristic form of this species. The largest shell in the collection has the following dimensions in millimeters :—

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
18·5	15·5	11·5	9·5

Gude's reference to " var. *aurantiaca* v. *rufo-cornea* " is not clear to me. He regards the variety *aurantiaca* as very distinct in appearance from the type in point of colour, which by itself is an unreliable character for differentiation of even a variety.

Succinea tornadri,[1] sp. nov.

The shell of this species is oblong-ovate, broadly conical at apex, moderately thick with close-set fine oblique striae. The spire is broad with a well-impressed oblique suture and has a papillate apex. There are three whorls in the spire, the last being broadest above. The aperture is somewhat broadly ovate with its apex more or less rounded, while the columellar margin, which is usually inflexed below the callus, has its fold very thin and broad with an elongated smooth and prominent ridge. The outer margin of the aperture is oblique and nearly straight. The colour of the shell is yellowish corneous.

Type specimen.—No. M $\frac{12380}{2}$ in the Zool. Surv. Ind. (*Ind. Mus.*).

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
15·2	11·8	9·5	7·0

[1] The word *Adri* in Sanskrit means a hill.

Three shells of this species were obtained by Blanford from the Torna Hills in Poona with those of *S. collina*. Nevill did not record these specimens in his Hand List. They were regarded as a variety of *S. collina* by Blanford but never described as such. I find a label bearing his name with the shells.

The present species, though allied to *S. collina*, differs from it in having a more tumid body-whorl, in the outer margin of the aperture being straight and oblique, in having two complete whorls in the spire, in the less coarse sculpture, in the greater prominence of the lower extremity of the columellar ridge, in colour, and in the absence of pearly lustre on the inner surface of the shell.

Succinea girnarica Theobald.

1873. *Succinea girnarica*, Sowerby in Reeve, *Conch Icon*, pl. i, fig. 5*a*, 5*b*.
1914. *Succinea girnarica*, Gude, *op. cit.*, p. 451.

Shells of this species collected by Theobald from the Girnar Hills in Kathiawar and recorded by Nevill are still in the collection. One of the shells has its aperture closed by an epiphragm, and from another small shell in which the animal was dried and attacked by fungus I have been fortunate enough to extract the jaw and the radula.

The larger shells have a superficial resemblance to those of *S. collina*, but differ from it in colour, texture and sculpture, and in the less tumid penultimate whorl. The smaller shells, of which there are only three, resemble those of *S. rutilans*, but are easily distinguishable from the latter by the colour and texture of the shell.

Measurements in millimeters.

	Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
Largest shell	24·0	19·0	14·5	11·5
Small shell	8·5	6·8	5·5	4·9

The jaw is very distinct and differs from that of all other Indian species. It is longer than broad and the cutting piece is about $\frac{2}{3}$ as broad as the accessory basal plate. The apices of the arms are broadly rounded and the concavity between them is relatively shallow and broadly truncated at the bottom. The accessory plate narrows gradually from before backwards and has its posterior margin more or less straight and transverse.

The radular ribbon is relatively broad and consists of moderately large teeth, the approximate radular formula being 44·14·1·14·44. The cusps of the teeth are shorter than the basal plate which is very much narrowed in the last few marginals as in *S. indica*. The central is broad and has a conical cusp with obsolete or sub-obsolete lateral teeth. The laterals have only two cusps of which the entocone is much larger. The marginals are very characteristic of this species, and appear to be intermediate between those of the aculeate and quadrate forms. They have two long incurved cusps with one, or rarely, two smaller and narrower cusps between them.

Succinea elegantior Annandale.

1921. *Succinea elegantior*, Amin-ud-din, *Rec. Ind. Mus.*, XXII, pp. 593–598, text figs. 20, 21 (1), 22, 23, 24.

Shells of this species are apt to be confused with those of *Indosuccinea semiserica*, for in general outline they seem to agree. The

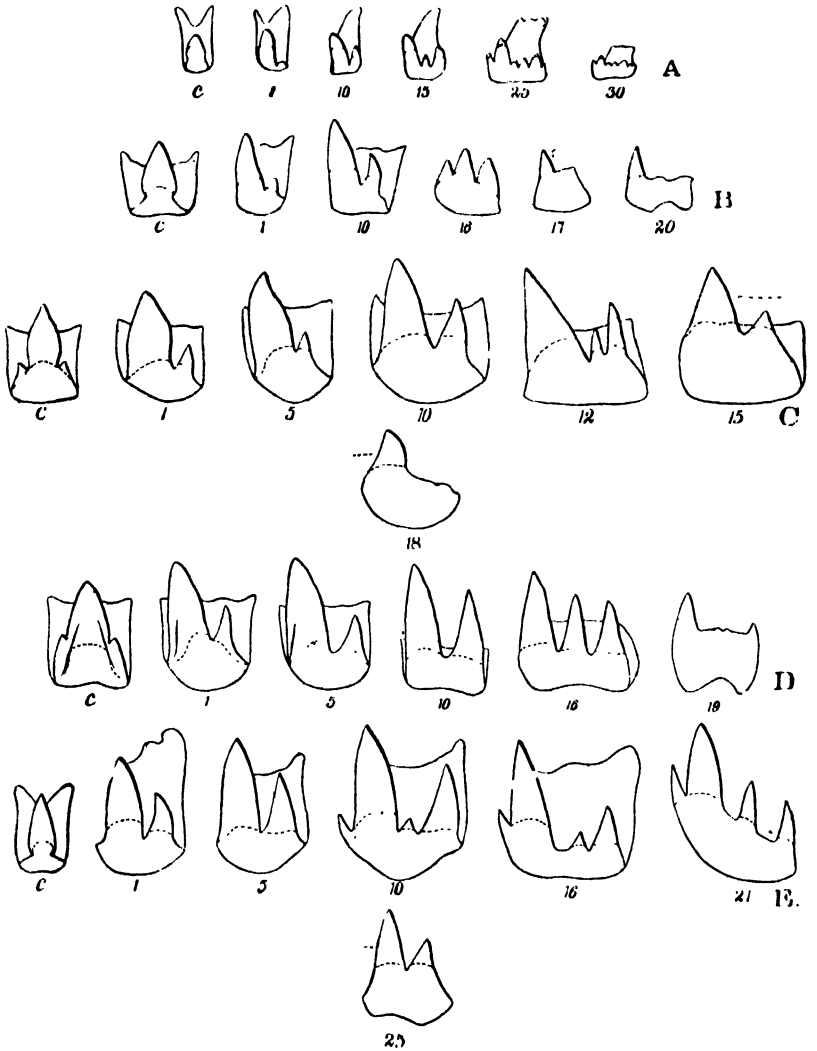


FIG. 3.—Radular teeth of Succineidæ.

A. *Camptonyx theobaldi* Benson from Girnar Hills, Kathiawar.
B. *Lithotis tumida* Blanford from Singhur, Poona.
C. *Succinea crassinuclea* f. *vitrea* Pfeiffer from Port Canning, Bengal.
D. *Succinea bensoni* Pfeiffer from Bombay.
E. *Succinea subgranosa* Pfeiffer from Kumaon.

fine golden hue of the present species, its relatively narrow, less tumid spire, with an oblique suture distinguish it from the latter. The soft parts, however, closely resemble those of the other amphibious species.

The radular teeth, though relatively large, conform to the type in *S. indica*, but are stouter and stronger. The marginals are, however, distinct in that the secondary cusps are stout, short and rounded.

The jaw approaches that of *S. indica* in general form but differs from the latter in that the arms of the cutting piece are more or less horizontal and uniformly broad, and the median projection is much less prominent. The jaw is probably just as variable in form as in *S. indica*.

In the description of the alimentary system in the work cited no mention is made of the presence or absence of caeca at the junction of the stomach and the intestine. There is unfortunately no well preserved material in the collection to elucidate this point. They are presumably present as in the allied *S. indica*.

In figure 22 (*a*) of the work cited there is a very short pouch close to the base of one of the seminal vesicles which seems to correspond to the narrow compressed, elongated accessory sac described in *I. semiserica*. All the three sacs open into the fecundation pouch from which start the uterus and the vas deferens.

The species has hitherto been recorded only from the lakes and swamps of the Manipur valley.

Succinea crassinuclea Pfeiffer.

1876. *Succinea crassiuscula*, Hanley and Theobald, *op. cit.*, p. 30, pl. lxviii, figs. 5, 6.
1878. *Succinea crassiuscula*, Nevill, *op. cit.*, p. 212.
1923. *Succinea crassinuclea*, Annandale and Rao. *Rec. Ind. Mus.*, XXV, p. 395.

Shells of this species recorded by Nevill in his Hand List are, with the exception of two from Kutch, still in the collection. There are also four large shells from Samole in Malwa, and a single shell from Simla, both collected by Taylor.

Measurements in millimeters.

Locality.	Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
Malwa	13·6	10·5	7·6	6·8
Calcutta	13 1	9·1	7·5	6·0
Simla	11·0	7·8	7·0	6·0
Salt Range	10·3	7·2	6·5	5·3
Karachi	8·6	5·3	5·5	4·0

The species is variable both in colour and form of the shell and is indistinguishable from *S. vitrea* Pfr. Examining specimens of the same size and growth of the two species together one finds it difficult to separate them. When they are, however, separately examined it is possible to find a few points of difference, but I am unable to agree with Gude (*op. cit.*, p. 455) that the points of difference are sufficient to justify the retention of *S. vitrea* as a distinct species.

The shells vary in colour from pale yellow or cream to pink, and also in the height of the spire and the tumidity of the body-whorl.

The dried remains of the animal seem to have been carefully removed from the shells, and no idea can be formed of the nature of the jaw and the radula.

The occurrence of the species from the Salt Range and Karachi in the extreme west, Simla in the north and Calcutta in the east seems to be an indication of its probable wide distribution in Northern India.

Succinea crassinuclea f. **vitrea** Pfeiffer.

1876. *Succinea vitrea*, Hanley and Theobald, *op. cit.*, p. 29, pl. lxviii, figs. 2, 3.
1914. *Succinea vitrea*, Gude, *op. cit.*, p. 454.

Individuals of this form, though closely resembling those of *S. crassinuclea* Pfr., can be distinguished by certain features in the shell. But they are, however, not sufficiently marked to raise the members of the present form to the rank of a distinct species.

This form has a more tumid and less oblique body-whorl than in *S. crassinuclea*, and a shorter spire which has, as a rule, only two whorls of which the apical is much less prominent than in the species. The shells from Calcutta are intermediate in character and have $2\frac{1}{2}$ whorls in the spire.

The Indian Museum collection contains specimens from Calcutta, Port Canning and Dacca in Bengal, Patna in Bihar, and Roorkee in the United Provinces. All except those from Bihar have been recorded by Nevill. The form has also been recorded from Bombay, the Andaman Islands, and the Laccadives. It is probably, more widely distributed than we know.

Measurements in millimeters.

Locality.	Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
Port Canning (Bengal)	9·0	7·1	6·0	4·8
Patna	7·8	5·7	5·0	4·3
Roorkee	9·8	8·0	6·8	5·1
Calcutta	11·0	7·8	7·2	4·8

The jaw and the radula have been extracted from the dried animal in one of the shells. They are distinct from those of other species, and a glance at the figures will enable one to appreciate the differences in the form of these structures in different species of the genus. The cutting piece of the jaw in the present form has its arms considerably short while its apices have a rounded posterior margin with definite angulation at the junction of the anterior and posterior margins. The striation on the cutting piece and the basal accessory plate is not conspicuous. The anterior margin of the former is depressed slightly and bears no prominences or tubercles. The basal accessory plate is sub-quadrate and narrows from behind forwards, and its posterior margin is also slightly concave in the middle.

The radula is ribbon-shaped with the number of teeth in each transverse row remarkably few. Individual teeth are relatively large in size and their cusps exceed, as a rule, the height of the basal plate. The central has a large median acuminate cusp with a prominent tooth on each side. The laterals vary in number to a limited extent but are never less than ten. The teeth are narrow and conical. The marginals are fewer in number than the laterals. The approximate radular formula is 4·14·1·44·4. There may be 12 to 15 laterals and 3 to 6 marginals on each side of the central.

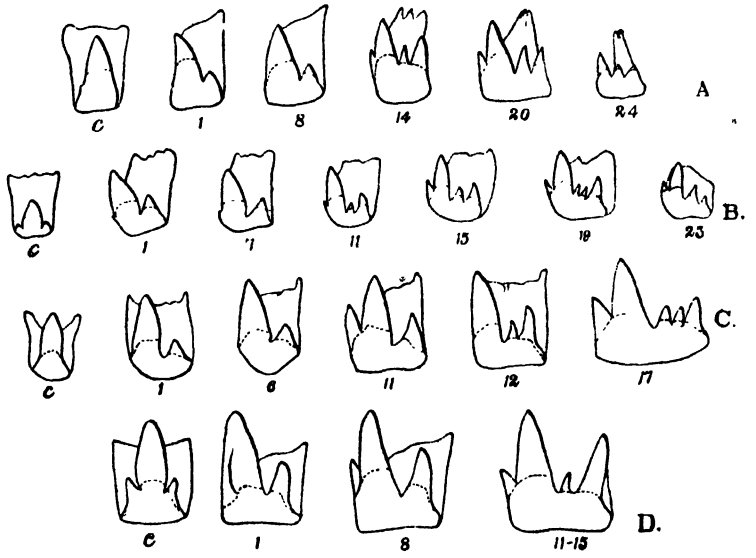


FIG. 4.—Radular teeth of Succineidae.

A. *Succinea stoliczkae*, sp. nov. from "Karnag."
B. *Succinea gravelyi*, sp. nov. from Adyar, Madras.
C. *Succinea rutilans* Blanford from Manipur
D. *Succinea godwiniana* f. *rangiya*, nov. from Port Canning.

The radular teeth approach in some respects those of a form of *S. godwiniana* Gude from Port Canning to be described further on, but differ from them in the absence of the small tooth at the inner base of the entocone of the outer laterals and of the marginals.

Until the anatomy of *S. crassinuclea* is known it is difficult to determine the exact relationship of the present form to the species mentioned. So far as the shell is concerned there is no doubt as to their close relationship.

Succinea martensiana Nevill.

1878. *Succinea martensiana*, Nevill, *Sci. Results Sec. Yarkand Expdn. Moll.*, p. 5, figs. 30–31.

I include this species in the present note with some hesitation. Our collection contains several dry shells of this species bearing the label "Bazrahat, March 1894." They agree exactly with the figures of the

species in the work cited. The precise geographical position of the locality noted in the label is, however, not clear. I have failed to find it in the Atlases and in the volumes of the Imperial Gazetteer. The species was discovered by Stoliczka at Sasak Taka and Pasrobat in Yarkand and first described by Nevill in his report on the Yarkand molluscs. In his Hand List published in the same year as the Yarkand Report Nevill recorded shells from Yarkand and "Bazrahat" both collected by Stoliczka. It seems to me that shells from the latter locality were

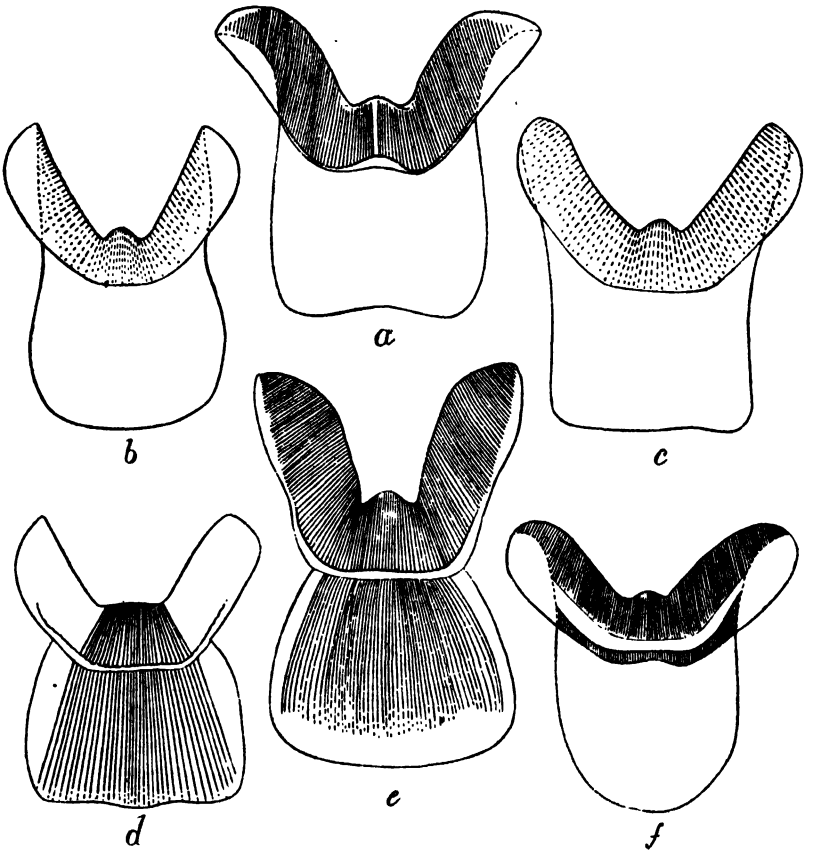


FIG. 5.—Jaws of Succineidae.

a. Succinea pfeifferi var. *recta* Baudon from Luchon, Europe.
b. Succinea indica Pfeiffer from Peshawar.
c. Succinea indica Pfeiffer from Dal Lake, Kashmir.
d. Succinea pfeifferi Rossmässler from Candahar.
e. Succinea putris var. *propinqua* Baudon from Burgos, Spain.
f. Succinea yarkandensis Nevill from Yarkand.

collected after the publication of the Yarkand Report and before that of the Hand List. For if "Bazrahat" was in Yarkand, Nevill would not have failed to record shells from this locality in his Report. I believe that "Bazrahat" is a mispelling of Basirhat in the 24-Parganas in Bengal, especially when I find that "Sasak Taka" is spelt "Sasstekke" in the Hand List.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
13·5	9·0	7·5	6·0
12·0	8·0	6·4	4·6
11·0	7·5	6·4	4·5
12·8	8·2	7·3	5·5

I was fortunate enough to find a single shell in the collection with a tiny bit of the dried animal which proved to be the anterior half containing the jaw and the radula. These structures were carefully removed by treatment with caustic potash.

Like the shell, the jaw and the radula are very characteristic of this species, and a comparison of the figures with those of the same structures of other species will show the distinctive features.

The jaw is fairly strongly chitinised, and is about as broad as long. The cutting piece is much better chitinised than the basal accessory plate and bears on its anterior margin three broad rounded prominences, one at the bottom of the concavity and two on the sides midway between the apex and the median prominence. The apex of the arms is bluntly conical. The posterior margin of the cutting piece is slightly depressed in the middle. The accessory plate has more or less parallel sides, while its posterior margin has a median concavity.

The radula is a broad ribbon consisting of fairly large teeth, which are stout and conical. The central has a stout cusp with an insignificant shelf-like projection near its base but has no definite lateral cusps. The laterals are more or less uniform in shape and have only two cusps. The ectocone is much smaller than the entocone in the first few laterals but show a progressive growth until the last lateral is reached, where the ectocone is many times larger than the entocone. The marginals are aculeate and half as numerous as the laterals. They have three cusps of which the entocone is the largest and the remaining small and equal in size. The approximate radular formula is 10 19 1 19·10.

Shells from " Bazrahat " are smaller and thinner than the type-series and do not have the characteristic yellowish brown colour on the inner surface of the shell. They have some resemblance to those of *S. girnarica* and the larger shells of *S. crassinuclea* in general form, but the peculiar irregularly malleated appearance and coarse sculpture, and the elongate scalariform spire with convex whorls, distinguish them from the shells of either species.

Succinea hanleyi Gude.

1914. *Succinea hanleyi*, Gude, *op. cit.*, p. 455, fig. 141.

I refer to this species, with some doubt, a single broken shell from Pegu in Burma. It is smaller than the type and is of a pale colour. The whorls of the spire are more convex. The aperture and sculpture of the shell are similar to those of the type. The elongate columellar tubercle is very feebly developed. The author of the work cited considers that Hanley and Theobald's figure of *S. subgranosa* Hanley and Theobald is

referable to his species. The aperture of the shell figured by the latter is very different from that of the former. The species is apparently variable.

Succinea subgranosa Pfeiffer.

1873. *Succinea subgranosa*, Sowerby in Reeve, *op. cit.*, pl. iv, fig. 24.
1878. *Succinea oblonga*, Nevill, *op. cit.*, p. 211.

There has been some confusion in distinguishing the members of this species from those of *S. oblonga* Draparnaud and *S. bensoni* Pfr. The specimens of the present species in our collection have been in obscurity until by careful examination they were separated from the species with which they were confused.

Shells from Kutch and Bombay collected by Stoliczka and Fairbank respectively were recorded by Nevill as belonging to *S. subgranosa*, but that they are really *S. bensoni* is shown in the account of that species below. Three shells from Kashmir labelled "*S. oblonga*" and recorded as such by Nevill are, in fact, *S. subgranosa*. The latter species has, no doubt, some external features in common with the former, but is distinct anatomically. I have extracted the jaw and radula of a specimen from Kumaon. The jaw of *S. subgranosa* is very different from that of *S. oblonga* [1]. I am not aware of any published figures of the radula or the genitalia of *S. oblonga*, but I presume that like the jaw they also are different.

I refer three shells from Ceylon to this species. They were found in a box containing shells of *S. ceylanica* Pfr. with which they do not, however, agree. They closely resemble shells of *S. subgranosa* from Kashmir and Kumaon.

Measurements in millimeters.

Locality.	Height of shell.	Height of aperture.	Greatest breadth of shell	Greatest breadth of aperture
Kashmir	7·1	4·7	4·5	3·0
	7·3	3·8	3·6	3·0
Kumaon	6·0	3·2	3·0	2·6
Ceylon	6·1	3·6	3·8	3·0

The jaw is relatively less strongly chitinised and is broader than long. The cutting piece is uniformly striated, and the arms are gradually narrowed towards the apex and together form the arc of a circle. Its free margin is unindented. The basal accessory plate is slightly broader behind than in front and has a shallow depression on each side of the posterior margin.

The radula consists of relatively large teeth, and the cusps are all long, sharp and conical. The central has a spear-shaped median cusp

[1] Hazay, *Mal. Blätt.*, III, pl. vi, fig. 19.

and is without lateral projections. The entocones of the laterals and marginals exceed the height of the basal plate. The marginals have a

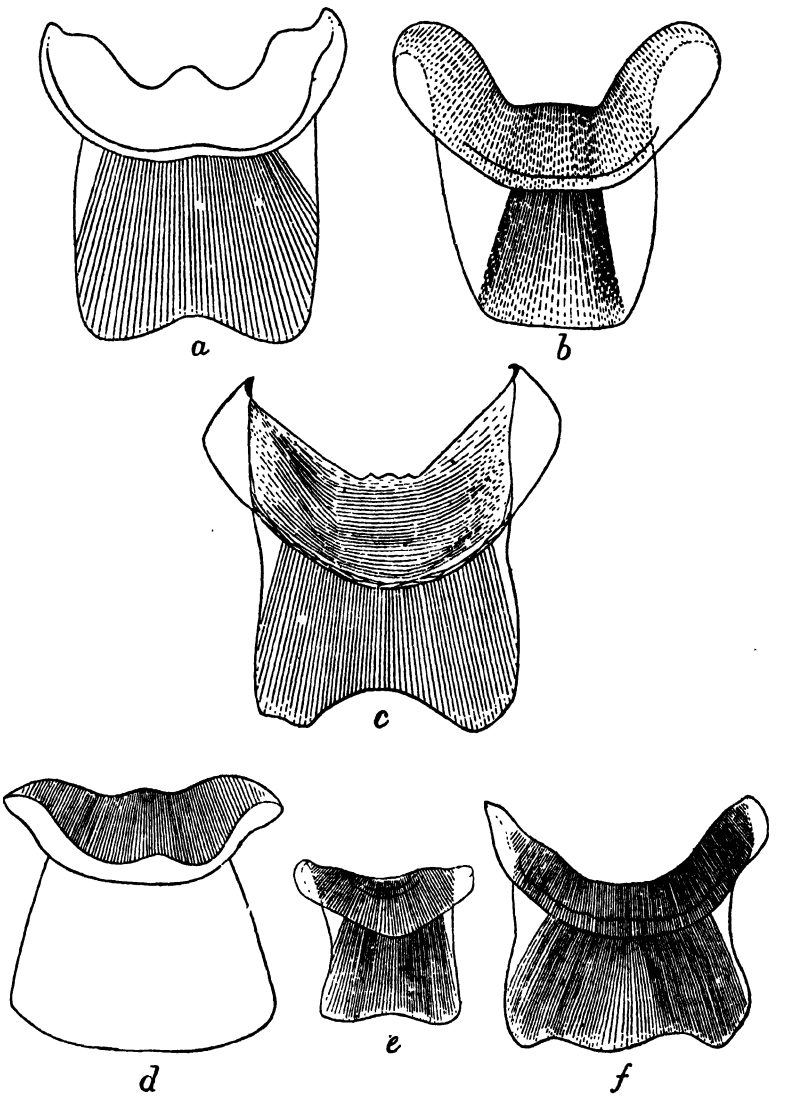


FIG. 6.—Jaws of Succineidae.

a. *Succinea martensiana* Nevill from Sasstekke, Yarkand.
b. *Succinea girnarica* Theobald from Girnar Hills, Kathiawar.
c. *Indosuccinea semiserica* (Gould) from Rangoon.
d. *Lithotis tumida* Blanford from Singhur, Poona.
e. *Camptonyx theobaldi* Benson from Girnar Hills, Kathiawar.
f. *Succinea subgranosa* Pfeiffer from Kumaon.

small tooth on the inner base of the entocone. The approximate radular formula is 16·9·1·9·16.

Succinea bensoni Pfeiffer.

1876. *Succinea bensoni*, Hanley and Theobald. *op. cit.*, pl. 67, fig. 9.
1878. *Succinea subgranosa*, Nevill, *op. cit.*, p. 212.
1914. *Succinea bensoni*, Gude, *op. cit.*, p. 456.

This species is represented in our collection by six shells from Bombay collected by Fairbank (from one of which the jaw and radula were extracted) and by a single shell taken by Stoliczka at Kutch.[1] Nevill does not record this species in his Hand List but has wrongly included the shells with those of *S. subgranosa*. Though the shell of *S. bensoni* has some superficial resemblance to a few short-spired forms of *S. subgranosa* the two species differ in important features. The latter has, as a rule, a thicker shell and a much longer spire, and in the soft parts has the jaw and radula very different from those of *S. bensoni*.

The type-series of *S. bensoni* from Moradabad are still in the collection and are not recorded by Nevill. Our specimens agree with them closely.

A single shell of *S. bensoni* was found mixed up with the shells of *Lithotis tumida* from Poona. As has been pointed out under the account of the latter species, the two species may be confused at first sight, but the real differences are given under the genus *Lithotis*. The columellar fold of this specimen from Poona is much better developed than in individuals from Kutch and Bombay.

The largest shell in the collection has the following measurements in millimeters :—

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
6·2	4·8	4·0	3·3

The jaw is relatively less strongly chitinised and is longer than broad. The arms of the cutting piece are short with the apices narrow and pointed. The anterior margin is very lightly depressed and may or may not have a median prominence. The posterior side of the cutting piece is rarely emarginate. The basal accessory plate has parallel sides and a depression on each side of its posterior margin.

The radular teeth are relatively few in number, the marginals being fewer than the laterals as in *S. crassinuclea* f. *vitrea*. The central has a well-developed median conical cusp with a lateral tooth at its base on each side. The laterals have much narrower cusps than in the above-named species with the entocones high and well developed. There are never more than five marginals, each having one or two cusps. The radular formula is approximately 4·1·5·1·1·5·4.

The jaw and radula are subject to variability to some extent in examples taken from the same locality. In spite of the fact that these structures in *S. bensoni* agree in some respects with those of *S. crassinuclea* f. *vitrea* I regard the two species as distinct. Judging from the

[1] I have since been able to collect living individuals of this species on the brick walls of the moat, Fort William, Calcutta, in the month of July 1923, and also from a drain in Sibpore in the same month.

shells alone one would be tempted to treat the present species as no more than a form of *S. crassinuclea* closely allied to the f. *vitrea*.

Living individuals of this species found in Calcutta enabled me to study the genitalia and other organs. The kidney and the pulmonary chamber show no peculiar features. The genitalia, on the other hand, somewhat resemble those of *S. indica*, but have certain distinct features. The albumen and hermaphrodite glands are well developed and the prostate is large and triangular. The uterus and the penis are slightly twisted together. There are three seminal vesicles as in *Succinea gravelyi*, sp. nov. The spermatheca is a globular sac with a long thin duct which opens at the junction of the broad distal portion of the uterus with the narrower convoluted proximal portion. There is a short vas deferens which opens on the top of the stout cylindrical penis which is bulged out at its proximal end, and to which is attached a single retractor muscle. The lumen of the penis has two longitudinal folds which enclose a groove. The terminal portion of the penis may often be protruded through the external opening as shown in the figure.

Living examples of this species are very sluggish in habits and live in crevices between stones and bricks which are overgrown with moss. The colour of the shell with the animal inside harmonises with that of its surroundings. They seem to live on moss growing in the crevices. They hardly contract when disturbed but exude copious mucous from the foot.

Succinea ceylanica Pfeiffer.

1876. *Succinea ceylanica*, Hanley and Theobald, *op. cit.*, p. 64, pl. clviii, fig. 10.
1878. *Succinea ceylanica*, Nevill, *op. cit.*, p. 212.
1914. *Succinea ceylanica*, Gude, *op. cit.*, p. 457.

I doubt whether this is a distinct species at all. It seems to be closely allied to *S. daucina* Pfr. and might prove to be only the Ceylon form of the latter. But nothing definite can be said about their affinities until the anatomy of both is known.

The single specimen in the collection from Kandy in Ceylon has a thick shell with $3\frac{1}{2}$ whorls and is relatively narrow. It agrees with the figure of this species in *Conch. Ind.* Though it approaches the typical forms of *S. daucina* in some respects, it differs from the latter in the body-whorl being relatively narrow, in the more deeply impressed suture and in the narrowly elongate aperture, the margin of which is slightly thickened. The colour of the shell is probably variable. It has the following dimensions in millimeters :—

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
9·6	6·4	5·4	3·8

Succinea daucina Pfeiffer.

1914. *Succinea daucina*, Gude, *op. cit.*, p. 453.

Several shells from Calcutta and Port Canning in Bengal are represented in the collection. Specimens recorded by Nevill are also intact.

The species is extremely variable in size, form and colour, but when the whole collection is examined at once it is possible to distinguish, at least, two distinct forms, *viz.*, the long-spired and the short-spired. The former are typical and agree with the original description of the

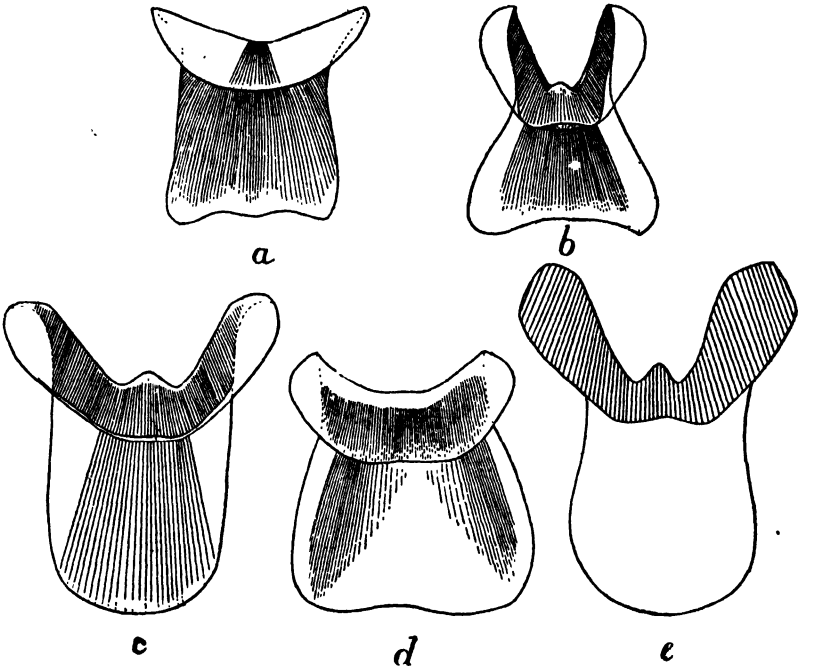


FIG. 7.—Jaws of Succineidae.

a. Succinea bensoni Pfeiffer from Fort William, Calcutta.
b. Succinea gravelyi, sp. nov. from Adyar, Madras.
c. Succinea stoliczkae, sp. nov. from Leh, Kashmir.
d. Succinea crassinuclea f. *citrea* Pfeiffer from Port Canning, Bengal.
e. Succinea stoliczkae, sp. nov. from "Karnag."

species, but not quite with the published figures. They are larger than the type. Gude distinguishes this species from its nearest allies by the inflexion of the outer margin of the peristome. This feature, owing to its variability, seems to me to be an unreliable diagnostic character.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
11·5	7·4	6 7	5 2
11 2	8·2	7·5	6·0
10·0	7·0	6·5	4·3
10·0	7·5	6·2	4·8
9·8	6·1	5·9	4·3

The anatomy is unknown. The shells in the collection have been so well cleaned that not a little of the dried animal is left behind to enable one to examine the jaw or the radula.

Succinea daucina f. hraswasikhara,[1] nov.

1878. *Succinea daucina* var. (?), Nevill, *op. cit.*, p. 212.

Shells belonging to this form were taken from the same localities as the previous species and found labelled "*S. daucina*, Pfr." In size they are smaller than *S. daucina* and have the spire shorter. They are subject to the same degree of variability in colour and form as the typical *S. daucina*.

The present form is, however, distinct and can be easily distinguished from the typical species by the relatively short spire, by the papillate apical whorl, and by the relatively less tumid penultimate whorl.

Shells intermediate in character between this form and *S. daucina* are also found in the collection, but they are not distinct enough to be regarded as a separate form.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
8·0	6·0	5·0	4·0
8·8	6·2	5·9	4·3

Type-specimen.—No. M $\frac{1\,2\,3\,9\,6}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

A small broken shell collected by Nevill in Madras is referred to this form.

Succinea snigdha,[2] sp. nov.

The shell is elongate-ovate, conical, moderately thick, shining, and has a pale cream colour. It has fine irregular striae which are conspicuous except on the spire. The spire is high, less than half the total height of the shell, and has $2\frac{1}{4}$ to $2\frac{1}{2}$ whorls, but rarely three. The whorls are tumid, the second more than the penultimate which is oblique and about $\frac{2}{3}$ the height of the spire. The suture is moderately impressed and the apex is minutely papillate. The aperture of the shell is elongate-ovate with the margins relatively thick. The columellar fold is minute or obsolete with a well-defined smooth and shining ridge continuous with the margin of the aperture.

Measurements in millimeters.

Type-specimen.	Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
	7·8	5·2	3·1	2·7
1	7·5	4·8	4·3	3·3
2	8·7	5·1	4·9	3·4

Type-specimen.—No. M $\frac{1\,2\,3\,9\,4}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Locality.—Calcutta.

Several shells of this species were found in a tube with the label "Calcutta" in the box containing *S. daucina*. Nevill does not record them in his Hand List.

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[1] From two Sanskrit words *Hraswa* (= short) and *Sikhara* (= spire).
[2] *Snigdha* in Sanskrit means smooth.

The species is slightly variable in size, thickness and sculpture of the shell, and in the prominence of the columellar ridge. The latter

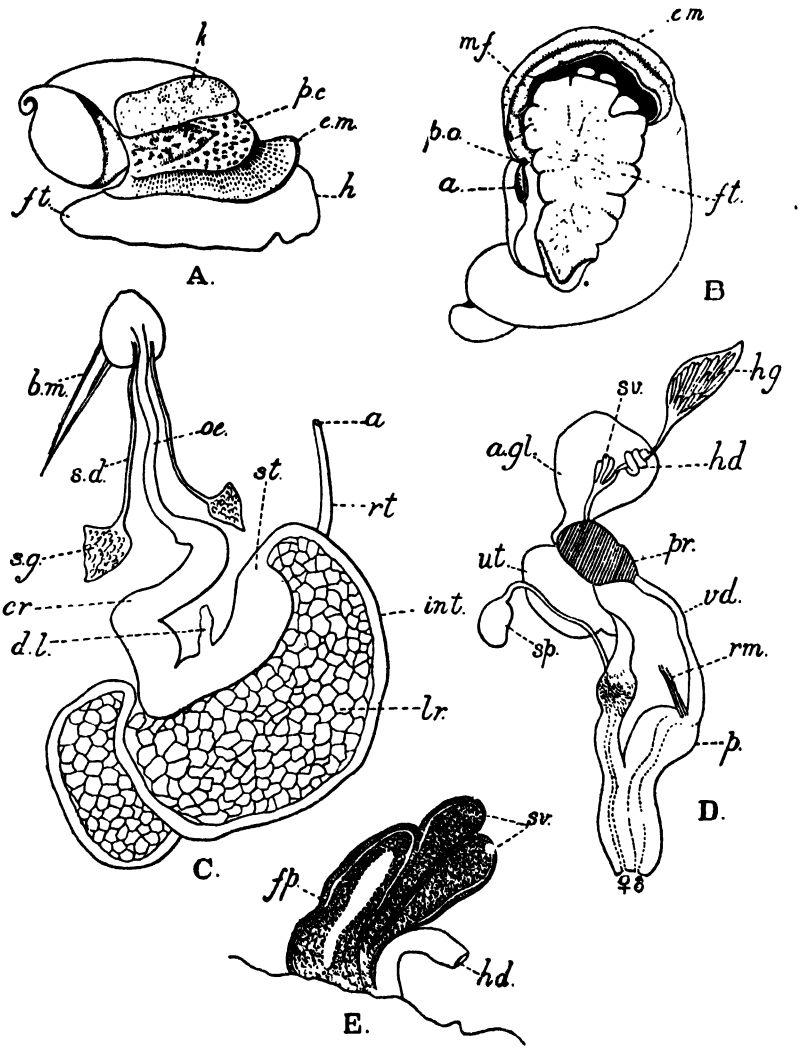


FIG. 8.—External features and anatomy of *Succinea gravelyi*, sp. nov.

A. View from the right side of the animal.
B. Ventral view of the whole animal.
C. Alimentary tract and associated structures.
D. Ventral view of the genitalia.
E. Enlarged view of the seminal vesicles.

a. anus ; *a. gl.* albumen gland ; *b.m.* buccal muscles ; *cr.* crop ; *d.l.* duct of liver ; *e.m.* edge of mantle ; *fp.* third seminal vesicle representing the modified fecundation pouch ; *ft.* foot ; *h.d.* head ; *h.d.* hermaphrodite duct ; *h.g.* hermaphrodite gland ; *int.* intestine ; *k.* kidney with calcareous concretions seen through covering membrane ; *lr.* liver ; *mf* fold of mantle ; *oe.* oesophagus ; *p.* penis ; *p.c.* pulmonary chamber ; *p.o.* plumonary opening ; *pr.* prostate gland ; *r m* retractor muscle of penis ; *rt.* rectum ; *s.d.* duct of salivary gland ; *s.g.* salivary gland ; *sp.* spermatheca ; *st.* stomach ; *s.v.* seminal vesicles ; *ut.* uterus ; *v.d.* vas deferens.

has often the appearance of a minute tubercle in an oblique ventral view from the columellar side. The ridge is separated from the body-whorl by an open shallow groove.

Though the present species resembles *S. daucina* in some respects, it differs from it in the smaller size, in the relative thickness of the shell, in being much narrower, in the possession of a relatively long spire for its size, in colour, in the distinct prominence of the columellar ridge and in the polished and shining appearance of the shell.

Succinea stoliczkae, sp. nov.

1878. *Succinea*, sp., Nevill, *op. cit.*, p. 214.

The shell is ovate, relatively thick, and has irregular relatively coarse striae. The colour of the shell varies from a pale cream to grey or brown with, sometimes, a characteristic shining appearance. The spire is elongate, obtusely conical, a little less than half the total height of the shell, and has 2½ to 3 scalariform, quite convex whorls, sculptured with fine oblique striae. The suture is nearly transverse and the body-whorl moderately convex. The aperture is ovate, obliquely flattened above on the columellar side, but regularly rounded below. The outer margin is somewhat arched above. The columellar fold is minute, twisted in the middle, and has a long, oblique, smooth and shining ridge commencing from within the aperture.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
8·9	5·5	5·6	3·7
8·0	5·5	5·1	3·0
7·5	4·6	4·4	3·1
7·3	4·0	4·2	2·6
7·0	4·0	3·9	2·5

The jaw is very distinct in several features. It is longer than broad and the cutting piece has long and club-shaped arms with a prominent median projection at the bottom of the concavity. The posterior margin of the cutting piece is medially depressed. The basal accessory plate is roughly rectangular with the posterior part broader and rounded.

The radula is a long narrow ribbon with less than 60 teeth in each transverse row. The teeth are relatively small and have sharp elongated cusps. The central has a conical median cusp with a subobsolete lateral tooth at its base. The laterals have, as usual, only two cusps, while the marginals have nearly always 4 cusps including the small tooth at the inner base of the entocone. The approximate radular formula is 16.13.1.13.16.

Type-series.—No. M $\frac{1\,2\,8\,9}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Several shells were taken by Stoliczka under stones at "Karnag."

I have been unable to determine the precise position of this locality in the Indian Empire. It is probably the name of a spring in Kashmir. Nevill recorded these specimens in his Hand-List as an undetermined species of *Succinea*.

Shells of this species approach those of *S. snigdha* in some respects, but are distinguished from the latter by the scalariform shell, the

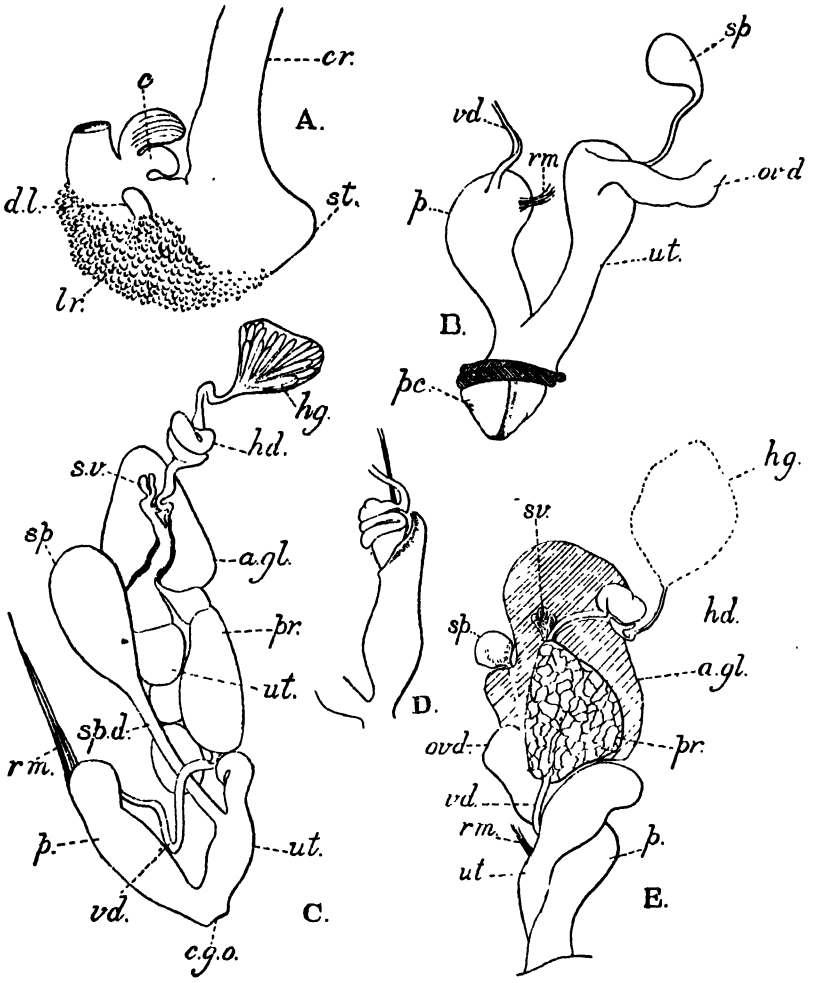


FIG. 9.—Anatomy of Succineidae.

A. *Indosuccinea semiserica* (Gould). Region of the stomach.
B. *Succinea bensoni* Pfeiffer. Terminal portion of the genitalia as seen from the ventral side with the structure dissected out.
C. *Succinea indica* Pfeiffer. Ventral view of the genitalia.
D. *Succinea indica* Pfeiffer. Penis dissected out from its sac, and showing digitiform process at its proximal end.
E. *Succinea bensoni* Pfeiffer. Ventral view of the genitalia (*in situ*).

a.gl. albumen gland ; *c.* caeca ; *c.g.o.* external opening of the male and female ducts ; *cr.* crop ; *d.l.* duct of liver ; *hd.* hermaphrodite duct ; *hg.* hermaphrodite gland ; *l.r.* liver ; *ov. d.* oviduct ; *p.* penis ; *pc.* portion of penis protruding outside with a median groove on it ; *pr.* prostate gland ; *rm.* retractor muscle of penis ; *sp.* spermatheca ; *sp.d.* duct of spermatheca ; *st.* stomach ; *sv.* seminal vesicles ; *ut.* uterus ; *vd.* vas deferens.

strikingly convex whorls, the coarser sculpture, the dull gray colour, and the nature of the aperture and the columellar ridge,

Succinea gravelyi, sp. nov.

The shell is narrowly ovate, relatively thin, translucent, and more or less regularly finely striated. It is of a reddish-amber colour except on the apex of the spire and on the columellar fold which are often pale in contrast. The spire is short, conical and less than $\frac{1}{3}$ the total height of shell, and has a blunt apex. It has, as a rule, $2\frac{1}{4}$ moderately convex whorls, the penultimate oblique and less convex than the last whorl. The suture is not deeply impressed. The aperture is ovate, pointed above and evenly rounded below, and rarely oblique from below the columellar fold. The outer margin of the aperture is very slightly inflexed above. There is often a pearly lustre on the inner surface of the shell. The columellar fold is very thin and minute while its ridge is nearly obsolete.

Measurements in millimeters.

	Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
Type specimen.	6·5	5·0	4·7	3·0
1	6·2	4·2	3·8	3·2
2	6·0	4·6	3·7	3·1

External features.—The foot of the animal in preserved condition is leaf-shaped, very much wrinkled, broad and rounded in front and tapering gradually behind. The sides of the head and the tentacles are covered by small dark patches of pigment which gradually fade on the sides and posterior extremity of the foot. The edge of the mantle is broad and pigmented, and has a groove near the free margin and a narrow vertically depending fold on its lower surface. The roof of the pulmonary chamber is thin and transparent and covered with sparsely distributed irregular patches of black pigment which fade away on the membranous covering of the spire. The kidney is roughly rectangular, and slightly broader on the right side than on the left. It is yellow in colour and filled with spherical or oval calcareous concretions. The spire has a pale pink colour. The mouth of the animal is a small circular opening, often very much contracted and hidden from view by the folds of the buccal mass and the foot. The anus is an elongated elliptical slit on the right side near the posterior end of the pulmonary chamber and is in communication with the small circular opening of the lung at its anterior end by a short narrow groove as in other species of *Succinea*. The male and female apertures are placed close together on the right side a little below the base of the tentacle.

The jaw is small and delicate and slightly longer than broad. The arms of the cutting piece form a roughly V-shaped structure and are a little broader at their apices than below. The outline of the apex is rounded on the outer side and straight on the inner. The bottom of the V-shaped concavity is raised in the centre into an obtusely conical prominence. The basal accessory plate broadens rapidly from before backwards and has a broad shallow depression on the posterior margin. The striations on the jaw are well marked. In some features the jaw of this species seems to approach that of *S. indica* but differs from it in having a wedge-shaped basal accessory plate, in the broad depression on the posterior margin, and in its delicate texture.

The radula is a narrow ribbon consisting of relatively few small teeth. The central is short and conical and has at its base on each side a well-developed conical tooth. The basal plate is broad and much higher than the median cusp. The laterals have two cups with a small one at the base of the inner side of the entocone. The marginals have 4 to 5 elongate narrow cusps of which the entocone is the largest, while the small tooth on the inner side of the entocone is better developed than on the laterals. The dental formula is approximately 13.10.1.10. 13. The radula is very distinct in features though some resemblance might be detected to that of *S. rutilans* and some specimens of *S. indica*. It is, in all probability, a chance resemblance rather than any real affinity.

The oesophagus is long and commences from the middle of the dorsal surface of the heart-shaped buccal mass, opening into the crop which is wider. The salivary glands are two in number and roughly triangular in shape, and have thin ducts nearly as long as the oesophagus. The ducts open into the buccal mass one on each side a little behind the commencement of the oesophagus. The crop opens into a wide stomach which together with the former forms a roughly V-shaped structure. The duct from the liver or the hepatic glands opens at the anterior end of the stomach. In the individuals dissected the stomach contained a disintegrated mass of moss or algae and was singularly devoid of hard particles of mud or sand.

The caeca, which are found in other species of *Succinea*, seem to be wanting in *S. gravelyi*. I dissected over a dozen individuals but found no caeca in any of them. If they are present at all they must be extremely delicate and transparent.

The intestine is long and narrow and has a double loop encircling the liver. The rectum traverses the right margin of the posterior half of the pulmonary chamber and opens to the outside close to the opening of the lung.

The kidney is filled with spherical or oval calcareous concretions which seem to obliterate the internal folds as in individuals of *S. indica* from Kashmir taken in July. But individuals of the present species were all collected in January. From the facts available as regards this phenomenon in *I. semiserica*, *S. indica*, and the present species, the real causes of this phenomenon are somewhat obscure though rainfall and a low temperature seem to regulate the deposition of concretions.

The genitalia of *S. gravelyi* are remarkable in certain features. The hermaphrodite gland is elongately triangular and lightly coiled at the apex of the spire. The hermaphrodite duct is relatively short, its terminal portion being spirally coiled and covered by dark pigment. It opens at the base of the seminal vesicles of which there are three. Two of them are sub-equal and thick-walled while the third is slightly shorter than the others, thin-walled and enlarged. The last corresponds to the third vesicle described in *I. semiserica*. I have found spermatozoa in all of them in transverse sections of the organ. The third sac[1] probably represents the modified fecundation pouch, which, in *S. putris*, is a wide sac into which the seminal vesicles open. The prostate is oval

[1] Jacobi describes, in *S. horticola*, Reinh, a small sac at the base of the vesicles under the name "*Befruchtungstasche*" (vide *Journ. Coll. Sci. Tokyo*, XII, p. 84, pl. vi, figs. 119*a* and *b*; 1898–1900), and I presume this corresponds to the greatly developed sac in *I. semiserica* and *S. gravelyi*.

and the vas deferens moderately long and narrow. The latter opens on the proximal extremity of the penis, which is a wide sac in close relation with the vagina. The penis and the vagina are, to a relatively great extent, united along their length, which marks off this species from all others in which the genitalia are known. In cleared preparations of this portion of the genitalia it is evident that the wall of the vagina and the penis are fused together on one side, while their proximal parts are separated. The male and female openings are placed close together in an atrium-like structure. There is a single retractor muscle attached to the proximal end of the penis. The albumen gland is roughly triangular. It is followed by a short and narrow oviduct which leads to an enlarged uterus. The proximal end of the vagina has a bulbous outline and is connected with the uterus by a short wide duct. The spermatheca is oval and has a long fine duct which opens dorsally on the bulbous portion.

Type-specimen.—No. M $\frac{12378}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Dr. F. H. Gravely obtained several living individuals on the brick walls of an old well (just above the water-level) at the back of a casuarina plantation on the Elliot's Beach, Adyar, Madras.

This species is very distinct from all others both in the characters of the shell and in the peculiarities of the soft parts. The shell has a general resemblance to that of *S. daucina* f. *hirasesikhara*, but is distinguished from the latter by its relative narrowness and thinness, by the less tumid penultimate and last whorls, by the obsolete columellar ridge, and by the beautiful reddish-amber colour. It might also be confused with that of *S. rutilans*, which, however, can be distinguished by the form and the colour.

Succinea gravelyi f. deccanensis, nov.

Shells of this form are apt to be mistaken for those of the typical *S. daucina*, but a closer examination of the texture, sculpture and colour of the shells will make the differences clear. They are, however, closely allied to those of *S. gravelyi* in the features mentioned. They are larger in size than the latter and are of a dull amber colour. The penultimate whorl is more convex and the suture more or less well-impressed. The sculpture is coarser, distinctly on the penultimate whorl but minutely on the apical. There are about $2\frac{1}{2}$ whorls in the spire. The largest shell has the following measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
9·5	6·8	5·1	3·8

Type-specimen.—No. M $\frac{12387}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Five shells of this form were collected by Mr. B. Sundararaj from a walled tank in a mosque, Kurnool town, Madras Presidency.

Succinea gravelyi f. andamanensis, nov.

Shells of this form approach those of *S. gravelyi* f. *deccanensis* but have more tumid whorls than in the latter or in *S. gravelyi*. The penultimate and the last whorls are relatively convex and have a very coarse sculpture. The colour of the fresh shells is deeper than in *S. gravelyi*.

The jaw, the radula, and the other soft parts are similar to those of *S. gravelyi*.

The type-specimen has the following measurements in millimeters :—

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
8·3	5·9	6·0	4·0

Type-specimen.– No. M $\frac{1\,2\,4\,2\,4}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Living specimens of this form were found by Dr. N. Annandale on Mount Harriet (1,100 feet), S. Andamans in December 1923 on damp soil at the base of banana trees in a garden, at some distance from water.

Succinea rutilans, Blanford.

1876. *Succinea rutilans*, Hanley and Theobald, *op. cit.*, p. 29, pl. lxvii, fig. 10.
1914. *Succinea rutilans*, Gude, *op. cit.*, p. 448.
1921. *Succinea rutilans*, Amin-ud-din, *op. cit.*, p. 598, figs. 21 (2*a*, 2*b*) and 25.

The shells collected by Godwin-Austen in the Khasi Hills and recorded by Nevill are still in our collection. In addition there is a single shell from the Manipur valley which has a light olive-brown colour. It is more elongate than the Khasi Hill specimens and has a higher and more tumid spire.

There are two shells in the collection labelled "*S. taylori*, Pfr. Singapore" which agree closely with the Manipur specimen. They are of a yellowish amber colour. I have little doubt that *S. taylori* is a synonym of *S. rutilans*.

Measurements in millimeters.

Locality.	Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
Manipur	9·6	6·5	5·3	3·7
Khasi Hills	9·6	6·1	5·0	3·6
Singapore	9·0	6·4	5·5	4·0

The shells from the Khasi Hills have a remarkably short spire, and are of a pale yellow colour with olivaceous longitudinal streaks on the last whorl.

The jaw of the species is very distinct in features. It has roughly a square outline. The cutting piece is more or less uniform in breadth and has short and blunt arms with flattened apex. Its anterior margin makes a semi-circle and is without indentations. The basal accessory plate has parallel sides and a rounded posterior margin.

The radular teeth are relatively few in number and have characteristic features. The basal plate is nearly always shorter than the highest cusp of individual teeth. The central has an elongated conical cusp without lateral teeth. The laterals are bicuspid with the ectocone much shorter than the entocone. The marginals have three to five cusps, of which the entocone is the largest. There is a large conical tooth on the inner side of the base of the entocone, which may be rarely absent on one or two of the longitudinal rows of marginals.

The genitalia are of the usual type in amphibious species and exhibit no distinctive features.

The species is, presumably, widely distributed in Assam, Burma and the Malay Peninsula. In the present state of our knowledge of the species of *Succinea* as a whole no definite statement as regards their distribution can be made.

Succinea godivariana, Gude.

1914. *Succinea godivariana*, Gude, *op. cit.*, p. 449, fig. 140.

A single shell, collected by me from a sand-like deposit on the sides of the He-ho Gorge, S. Shan States in March 1922, is referable to this species. It agrees very closely with the figures of this species in the "Fauna" volume, but has half a whorl more. The shell is amber-coloured.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
3·4	2·5	3·0	1·8

The type-series were collected by Beddome on Gorge Hill, "Godivari" (apparently misspelt for Gōdāvari in the Madras Presidency).

The distribution of this small species is interesting, in that it has been found in two such remote places as "Godivari" in India and He-ho in Burma. The species being the smallest in size is much more likely to escape the attention of collectors than the larger species, which are themselves so little known owing to their cryptic habits.

Succinea godivariana f. vangiya,[1] nov.

Two shells from Port Canning in Bengal are here regarded as a distinct form of the foregoing species. They were found in our collection with only the locality label. Nevill did not record them in his Hand-List. They had a muddy deposit on the outer surface of the shell which was curiously raised into minute spine-like processes. These latter gave them the appearance of a marine or estuarine species (like that of a spiny *Neritina*). On washing the shells in water the muddy deposit disappeared and their true affinity was discovered. One of them had a tough epiphragm on removing which the dried animal was found in the shell. It was soaked in cold caustic potash for a few hours and the animal removed for the extraction of the jaw and the radula. The former structure was, unfortunately, not to be seen.

The radular teeth are large for the size of the animal, and few in number. The basal plate of individual teeth is always shorter than the highest cusp. The central has a long conical and apically blunt median cusp and two well-developed lateral cusps. The laterals have two cusps, of which the entocone is larger. The marginals have 3 to 4 cusps, one of which is the inner lateral denticle at the base of the entocone. The cusps are elongate, narrow and more or less sharp. The approximate dental formula is 8. 7. 1. 7. 8.

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[1] *Vangiya* is the adjective form of *Vanga* in Sanskrit for *Bengal*.

The largest shell has the following measurements in millimeters :—

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
3·6	3·0	2·5	2·0

Type-specimen.—No. M $\frac{1\,2\,3\,0\,2}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

The shells are whitish in colour and are narrower and much less convex than those of *S. godivariana*. The sculpture is also much coarser. The margin of the aperture below the columellar fold is inflexed.

The present form seems to give a clue to the true distribution of *S. godivariana*, which, from its known *provenance* alone, is likely to be regarded as a species having a discontinuous distribution.

Succinea limnaeiformis, sp. nov.

The shell is narrow, elongate-ovate, fairly thick with fine, close-set regular longitudinal striae. It has a pale yellowish-brown colour. The spire is very short and about $\frac{1}{5}$ the total height of the shell with only two whorls. The penultimate is oblique and moderately convex with very minute longitudinal striae. The body-whorl is not at all tumid but is somewhat convex in a dorsal view. The apical whorl is minutely papillate. The aperture is somewhat oblique, elongate-ovate, apically acute, and has a moderately thick margin. The columellar fold is thin, elongate, broad above and narrowed below and is continuous with the lower margin of the aperture. There is a distinct shining columellar ridge a little above the middle of the columellar margin. The outer margin is evenly convex. There is an elongate open groove below the columellar fold comparable to an umbilicus.

Measurements in millimeters.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
6·5	5·5	3 5	3·2

Type-specimen.—No. M $\frac{1\,2\,3\,7\,4}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Dr. Sunder Lal Hora obtained two living shells from the edge of the White-crow tank near Yawnghwe, S. Shan States, Burma.

This species is very distinct from any of the Indian or Burmese ones, and is remarkably like a *Limnaea* in general appearance, but the nature of the columellar fold and the ridge and that of the spire is enough to put it at once as a *Succinea*.

ADDENDUM.

Since this paper went to press I have had the opportunity of examining a small collection of freshwater Gastropods made by Dr. Sunder Lal Hora near Amingaon in Assam, in which were found two specimens of *Succinea godivariana*. Fortunately the animals were in a good state of preservation and the jaw and the radula could be extracted.

The shells are of about the same dimensions as the Shan specimen with the spire very similar. The colour is somewhat paler,

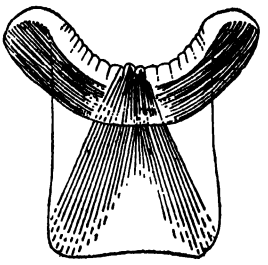


FIG. 10.—Jaw of *Succinea godivariana* Gude from Assam.

The jaw is very minute and rather feebly chitinised, but its outline and texture are well marked. The cutting piece is trough-shaped, and has short arms, with their apices broad and rounded. The anterior margin of the cutting piece is fragmented and has a characteristic appearance, while the remaining portion is transversely striated except for a triangular space in the middle. The basal accessory plate has parallel sides and a slightly depressed posterior margin.

The radular teeth are very similar to those of *S. godivariana* f. *vangiya* both in the number and form of the teeth in a transverse row.

The genitalia could not be made out owing to the delicate nature of the animal.

Specimens were apparently found in close association with Limnaeas attached to dead twigs and leaves in Thumarkur nullah, 3 miles from Sorupeta on the Amingaon side.

The occurrence of this species in the S. Shan States, in Assam and Bengal, and in the Madras Presidency far from its being an instance of local or discontinuous distribution would lend, in my opinion, ample proof of its wider distribution than we as yet know. The minuteness of the species is the only deterrent to our knowledge of its distribution but a careful collector to whom the minuteness of a species is no serious obstacle is bound to throw more light on this question.

Indosuccinea semiserica f. **khandalla,** nov.

Shells of this form are indistinguishable from those of f. *sthulasiras*. They are thin and brittle, and of a yellowish amber colour. They do not exceed 12 mm. in height. The sculpture and the thickening of the upper part of the body-whorl are variable but the latter is relatively prominent.

The jaw resembles that of f. *sthulasiras*, but has two chitinous thickenings running diagonally on the basal accessory plate from below the middle of the cutting piece towards the outer lower corners of the former. The striations on the remaining portions of the jaw is a little more conspicuous than in f. *sthulasiras*.

The radular teeth are very similar to those of *I. semiserica* and its closely allied form.

In the genitalia the duct of the spermatheca has no separate external opening but joins the oviduct some distance above the female aperture. The vas deferens is short and the penis relatively long. There are two seminal vesicles, sometimes unequal in length but without the sac corresponding to the fecundation pouch. It probably varies in prominence according as it is full of spermatozoa or relatively empty.

These differences in the anatomy of the animal seem, in my opinion, sufficient to warrant the recognition of this form as distinct from either *I. semiserica* or the allied f. *sthulasiras*.

Type-specimens.—No. M. $\frac{12\frac{4}{5}04}{5}$ Zool. Surv. Ind. (*Ind. Mus.*).

Several living specimens of this form were taken by Mr. R. Hodgart on shrubs growing in moist ground near Khandalla, Bombay Presidency, in July 1924.

EXPLANATION OF PLATE XXVIII.

Terrestrial and Amphibious Succineidae.

FIG. 1.—*Indosuccinea plicata* (Blanford) (×1·3), shell from Arakan, Burma.

FIG. 2.—*Indosuccinea semiserica* (Gould) (×1·6), shell from Moulmein, Burma.

FIG. 3.—*Indosuccinea semiserica* f. *sthulasiras*, nov. (×4), type-specimen from Calcutta.

FIG. 4.—*Succinea indica* Pfeiffer (×1·7), shell from Srinagar, Kashmir.

FIG. 5.—*Succinea indica* Pfeiffer (×2·3), shell from Pancha Tirla tank, Peshawar.

FIG. 6.—*Succinea indica* Pfeiffer (×2·3), shell from Thali-u, Inlé Lake, Southern Shan States.

FIG. 7.—*Succinea indica* Pfeiffer (×2·8), shell from Bhim Tal, Kumaon.

FIG. 8.—*Succinea indica* Pfeiffer (×1·7), shell from Dal Lake, Kashmir.

FIG. 9.—*Succinea indica* Pfeiffer (×2·5), shell from a field in He-ho, Southern Shan States.

FIG. 10.—*Succinea indica* f. *subfossilis*, nov. (×3·1), type-specimen from He-ho Gorge, Southern Shan States.

FIG. 11.—*Succinea daucina* Pfeiffer (×2·8), shell from Calcutta.

FIG. 12.—*Succinea daucina* f. *hrasvasikhara*, nov. (×3·4), type-specimen from Calcutta.

FIG. 13.—*Succinea gravelyi*, sp. nov. (×3·8), type-specimen from Adyar, Madras.

FIG. 14.—*Succinea gravelyi* f. *deccanensis*, nov. (×3), type-specimen from Kurnool, Madras.

FIG. 15.—*Succinea gravelyi* f. *andamanensis*, nov. (×3·1), type-specimen from Mt. Harriet, Andamans.

FIG. 16.—*Succinea stoliczkae*, sp nov. (×3·1), type-specimen from 'Karnag.'

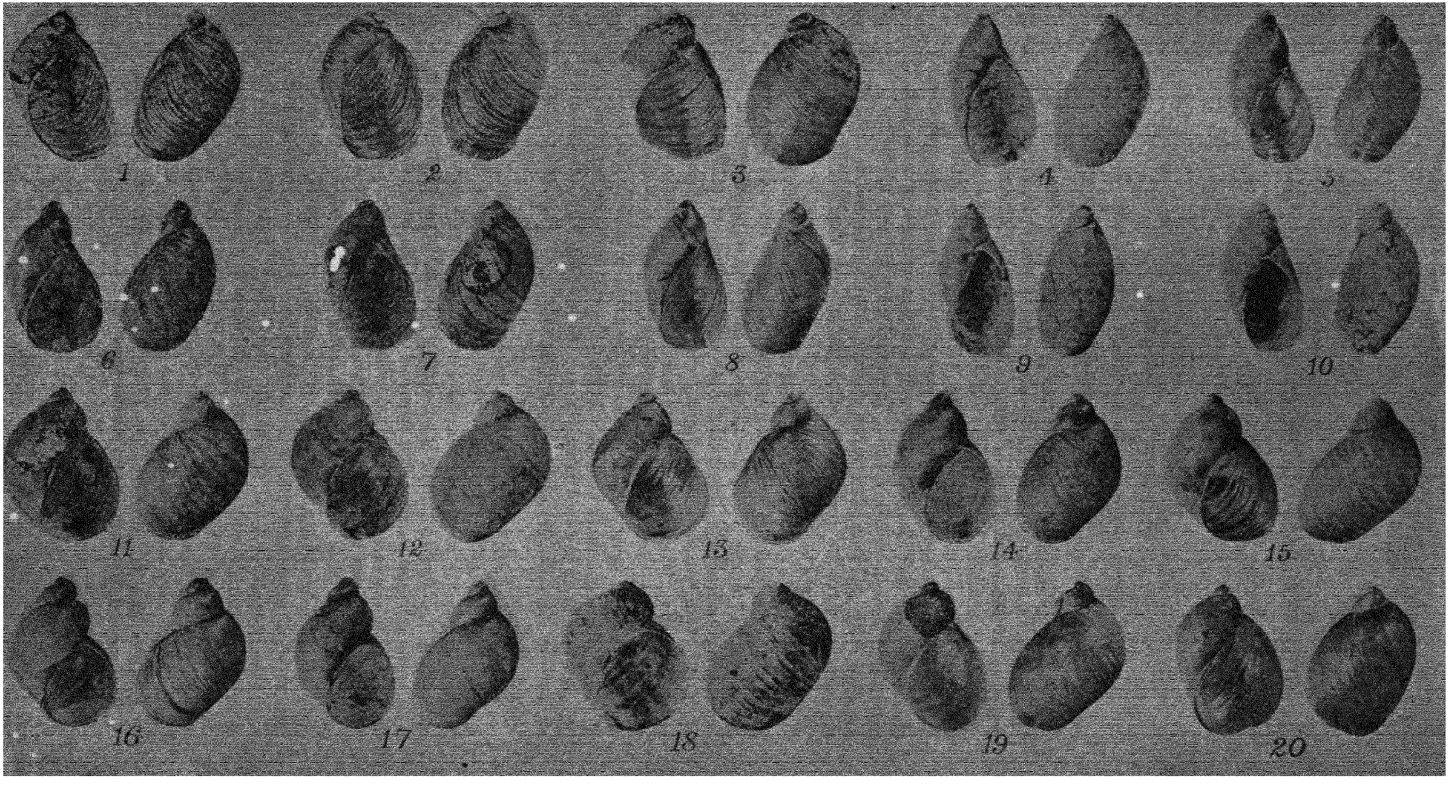
FIG. 17.—*Succinea snigdha*, sp. nov. (×3·1), type-specimen from Calcutta.

FIG. 18.—*Succinea godivariana* f. *rangiya*, (×6·3), type-specimen from Port Canning, Bengal.

FIG. 19.—*Succinea tornadri*, sp. nov. (×1·6), type-specimen from Torna Hills, Poona.

FIG. 20.—*Succinea limmaeiformis*, sp. nov. (×4), type-specimen from White-crow tank, Southern Shan States.

The figures within brackets indicate the magnification.



J. Mondul photo.

Asiatic Succincidae.

THE MOLLUSCS OF THE SALT RANGE, PUNJAB

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AND
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(Plate IX.)

A considerable collection of molluscs was made in the Salt Range by Theobald as long ago as 1851–52. Some of the species he obtained were described by Benson at different times, while all the Gastropods were recorded by Nevill in his *Hand List of Mollusca in the Indian Museum* (1878 and 1885). Dr. Sunder Lal Hora, whose introduction to the papers in this series may be consulted for particulars as to the physical conditions prevalent in the Salt Range, has brought back an interesting collection, particularly rich in aquatic forms. It should be noted that all his specimens are from that part of the range which lies east of the Indus. Unfortunately we have no particulars as to the precise localities in which Theobald collected his shells.

Considering the two collections together, we find specimens of 20 species of Gastropoda, 9 terrestrial (including a *Succinea* of unknown habits), and 11 aquatic. Of the 19 species of which anything precise is known, six have a wide distribution in the Oriental region, and seven in N. India. Four species are apparently endemic in the Salt Range while two were known hitherto only from the Baluchistan desert, Southern Persia and Iraq.[1] We may thus say that about 32 per cent of the Gastropods are Oriental in a wide sense and another 37 per cent Indian, while at least 21 per cent are endemic, and that there is some evidence of an element belonging to the Afghan fauna. The Afghan forms are aquatic as well as one of the endemic species, three of the latter being terrestrial.

Conditions of life in the Salt Range are very unfavourable for terrestrial and still more so for aquatic molluscs. The climate is dry and extremely hot for a considerable part of the year and much of the water is saline. Such a climate is not always inimical to the existence of a rich, or at any rate an abundant fauna of land snails, but the fact that the soil is impregnated with mineral salts is a most deterrent condition. For aquatic forms these factors, especially the last, are still more unfavourable. It is not surprising, therefore, that 69 per cent of the species are widely distributed in India or still further afield, for broad geographical range in a species in itself implies a physiological constitution readily adaptable to diverse conditions of life. That there should be a large endemic element in the Gastropod fauna might also be expected from the isolation of the Salt Range. It is interesting, however, to find that the Afghan fauna is represented. No species of this fauna has been

1. One of these (*L. persica*) has since been found in the Western Himalayas, at Peshawar and also (exceptionally) in the Deccan.

found hitherto east of the Indus. The occurrence of *Limnaea persica* and *Melanoides flavidus* is doubtless to be accounted for by similarity of conditions to be found in the Afghan-Baluch-Persian desert on the one hand and in the Salt Range on the other. This has enabled the fauna, or at any rate certain of its representatives, to spread into a territory which belongs geographically to the Indo-Gangetic plain.

The Pelecypoda collected by Dr. Hora belong to two widely distributed Indian species and have no particular geographical interest.

List of the Land and Fresh-water Molluscs of the Punjab Salt Range.

Gastropoda.

Terrestrial Species.

Fam. Helicidae.		
Eulota pentepotamiensis, sp. nov.		Endemic.
Fam. Testacellidae.		
Ennea bicolor (Hutton).		Peregrine.
Fam. Bulimindae.		
Buliminus salsicola (Benson).		Endemic.
B. *dextrosinister*, sp. nov.		Do.
Pupoides coenopictus (Hutton).		Drier parts of India.
Pupoides lardeus (Pfeiffer).	Not recorded.	Possibly endemic.
Fam. Achatinidae.		
Opeas gracile (Hutton).		Peregrine.
Zootecus insularis (Ehrenberg).		Do.
Fam. Succineidae.		
Succinea crassinuclea (Pfeiffer).		N. India.

Aquatic species.

Fam. Hydrobiidae.		
Amnicola (*Alocinma*) *pulchella* (Stoliczka).		N. India ; Assam.
Fam. Melaniidae.		
Melanoides tuberculatus (Muller).		Africa to New Guinea.
Melanoides flavidus (Nevill).		Iraq ; S. Baluchistan.
Fam. Limnaeidae.		
Limnaea acuminata Lamarck.		India ; Burma.
Limnaea luteola Lamarck.		India ; Burma ; Mauritius (? introduced).
Limnaea persica Issel.	S. Persia ; S. Baluchistan ; N. India ; Deccan.	

Pelecypoda.

Fam. Cyrenidae.	
Corbicula striatella Deshayes.	India.
Fam. Unionidae.	
Indonaia caeruleus (Lea).	India

TERRESTRIAL SPECIES.

Eulota pentepotamiensis, sp. nov.

1878. *Nanina* (*Bensonia*) *jacquemonti* Martens (in part). Nevill, *Hand List Moll. Ind. Mus.*, I, p. 49.

The shell is depressedly conoidal, almost flat below and with a very broad short spire, moderately thick, translucent white when fresh, often with a narrow brown stripe running round above the suture and the periphery of the body-whorl. The spire is flatter in some shells than in others, but is never acuminate. There are five and a half whorls, which increase gradually and evenly in size. The body-whorl is subcylindrical and without trace of a keel. The suture is linear and impressed. The mouth is lunate and almost horizontal as the last whorl descends very little, but there is some variation in this respect. The umbilicus is deeply perforate but always small. It varies considerably in size and in some shells is nearly closed. The edge of the lip is sharp and not at all reflected, and there are only slight indications, mainly on the upper part, of a thickening inside it. The columella is but slightly reflected over the umbilicus. The upper surface of the shell has an oily lustre, while the lower is highly polished. The sculpture consists of strong vertical striae, somewhat variable in development on the upper surface of the last four whorls, and of very much finer striae running in the same direction on those of the apex. On the lower surface the striae are also well developed except towards the mouth. A very minute spiral striation can be observed with a strong lens, especially on the upper surface.

Measurements of shells (in millimeters).

	Type	1	2	3	4	5	6
Major diameter	18·2	18·8	19·1	18·5	18·1	18·4	18·0
Minor diameter	16·5	16·8	16·8	16·0	15·8	16·0	15·6
Height	8·2	8·4	8·0	7·6	7·2	8·0	8·4
Greatest width of aperture	8·0	8·6	8·9	8·5	8·2	8·4	8·2
Height of aperture ...	6·5	7·1	7·1	6·9	6·6	6·8	6·8

This shell was confused by Nevill with that of *Bensonia jacquemonti*, to which it bears a certain quite superficial resemblance. It may easily be distinguished, however, by its size, texture and colour, and by differences in the shape of the mouth and the size of the umbilicus, which is always much smaller. The true relationships, in spite of geographical difficulties, seem to be with forms like *Eulota planispira*. The shell is, however, distinguished by its much more flattened form and very small umbilicus from that of *Eulota planispira*.

Type-specimen.—No. M $\frac{12126}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

We have examined a large series of shells, including those collected in the Salt Range by Theobald and assigned by Nevill to *Bensonia jacquemonti*. Dr. Sunder Lal Hora obtained numerous empty shells on the hillsides at Katas and two (smaller than the others) on the banks of the Katas Nallah, in July, 1922.

Ennea bicolor (Hutton).

1908. *Ennea bicolor*, Blanford & Godwin-Austen, *Faun. Brit. Ind., Moll.*, I, p. 19, fig. 12.

1921. *Ennea bicolor*, Annandale & Prashad, *Rec. Ind. Mus*, XIX, p. 189.

A single specimen was obtained by Theobald in the Salt Range.

Buliminus (Petraeomastus) salsicola (Benson).

1914. *Ena* (*Subzebrinus*) *salsicola*, Gude, *Faun. Brit. Ind., Moll.* II, p. 248.

The series collected by Theobald in the Salt Range and described by Benson is still intact in the Indian Museum.[1] We have selected two shells (M $\frac{12128}{2}$) as lectotypes and figure them here. As there is some individual variation, it is impossible to regard any one shell as typical. Dr. Hora did not rediscover the species.

Buliminus (Subzebrinus) dextrosinister, sp. nov.

1878. *Buliminus* (*Petraeus*) *eremita* (?) Hutton, Nevill, *Hand List Moll. Ind. Mus.*, 1, p. 134.

Specimens thus recorded by Nevill and collected by Theobald in the Salt Range agree precisely with some of those of a large series recently obtained by Dr. Sunder Lal Hora in the same range, but the latter show much greater individual variability and include many sinistral shells. Dextral specimens resemble those of the true *B. eremita* from Afghanistan and adjacent districts in many particulars but are quite distinct from those of *B. salsicola* and are as worthy of specific distinction as those of such forms as *B. sindicus*. The new species can best be described in comparison with *B. eremita*.

Apart from the fact that the shell in some localities is indifferently either dextral or sinistral and that at certain spots sinistral shells are more abundant than dextral, the most noteworthy differences are the following:—

(1) In *B. dextrosinister* the base of the body-whorl is much less compressed than in *B. eremita* and consequently the umbilicus is less conspicuous and the mouth less expanded in appearance.

(2) The shell is more elongate and has a more tapering spire than that of *B. eremita*.

(3) The body-whorl tapers slightly towards the base, giving the shell a somewhat spindle-shaped form.

(4) Both lips of the mouth are vertical and almost straight, running parallel to one another in such a way that the aperture forms an ellipse truncated obliquely at the posterior inner margin.

(5) The body-whorl is less inflated than in *B. eremita* and the outer lip projects less beyond its outer outline.

In fresh shells the colour is opaque white conspicuously streaked or spotted with transparent brown.

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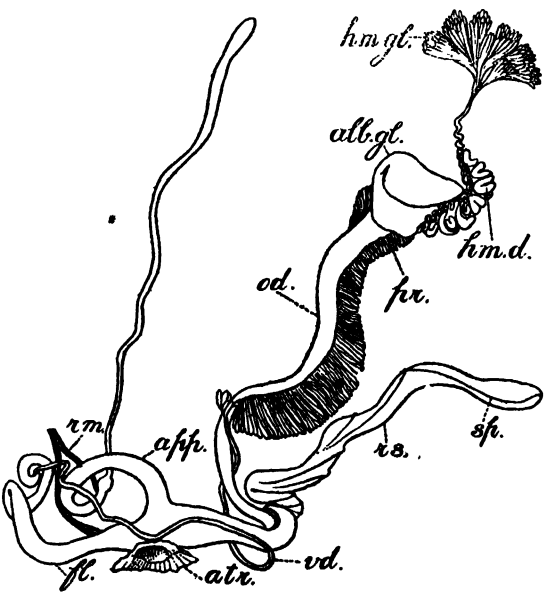
[1] The author of vol. II on the molluscs in the official "*Fauna of British India*," appears to be unaware of the fact that many of Benson's types are in the Indian Museum.

In sinistral shells the body-whorl has a somewhat distorted appearance and the outer lip projects further and is more curved than in dextral shells. Such shells are also a little larger than dextral specimens.

Shells in our large series exhibit considerable variation in outline, but the characters given above seem to be constant.

External characters of the animal.—The foot is narrow and pointed and a pair of tentacles are present in addition to the eye-stalks. The specimens that we examined were too much contracted to provide detailed information as to external features in other respects.

The genitalia agree in general structure with those of the Chinese species described by Wiegmann[1] except in one important feature, namely, the complete absence of a diverticulum on the copulatory pouch. The male and female ducts open into a common atrium situated, in a dextral shell, on the right side of the body a little behind the eye-stalks. The hermaphrodite gland, as in certain species figured by Wiegmann, Jacobi[2] and Beck,[3] is racemose or rather finely lobulate. Its duct is much convoluted, especially towards the lower extremity. The albumen gland is large and elongate, sometimes folded on itself but



TEXT FIG. 1. –Genitalia of *Buliminus dextrosinister*, sp. nov. (dextral shell). *alb. gl.* albumen gland; *atr.* genital atrium; *app.* appendage; *hm. gl* hermaphrodite gland; *hm. d.* hermaphrodite duct; *fl.* flagellum *od.* oviduct; *pr.* prostate; *rm.* retractor muscle of flagellum; *rs* receptaculum seminis; *sp.* spermatophore pressed against the walls of the receptaculum seminis; *vd.* vas deferens.

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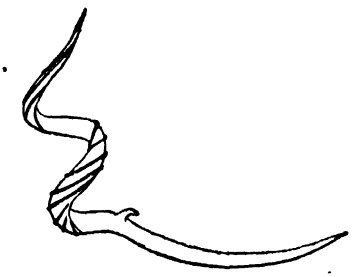
[1] Wiegmann, *Ann. Mus. Acad. Imp. Sci. St. Petersburg*, VI, pp. 220—290, pls. x-xi (1901).

[2] Jacobi, *Journ. Coll. Sci. Tokyo*, XII, pp. 76—82, pl. vi, figs. 113—115 (1898—1900).

[3] Beck, *Jenai. Zeitschr*, Jena XLVIII, pp. 187—225, pp. viii—x (1912).

straight in some individuals. The oviduct is broad and simple in structure. The copulatory pouch, which arises not very far from its base, is comparatively short and blunt at its extremity. There is no trace of the diverticulum.

In one of the specimens examined the pouch contained two spermatophores. These were vermiform bodies sharply pointed at both ends with a hooked process on one side near the middle and bearing a closely-wound chitinous spiral keel on one half. One extremity, that without keel, was bent in a regular wide arc for almost half of the



TEXT FIG. 2.—Spermatophore of *Buliminus dextrosinister*, sp. nov.

length of the whole structure, while the other was twisted in an open spiral of three whorls.

The male part of the genitalia differs less than the female from that of previously described species of *Buliminus*. The penis-sheath is elongate and almost filiform but slightly dilated at the tip. The flagellum and the vas deferens are normal. The prostate is an elongate, band-shaped gland lying in close contact with the oviduct.

Alimentary System.—The jaw resembles that of *Buliminus* (*Subzebrinus*) *beresowskii* but is not so stout or deep.

The radula has the approximate formula 14. 10. 1. 10. 14. The teeth differ from those of *Buliminus reinianus* in that the main cusp is relatively larger, especially on the marginals, but are of the same type.

The alimentary canal is long and coiled. The oesophagus has thickened walls and its lumen is raised into folds. The stomach and intestine are wide and thin-walled.

In sinistral shells the soft parts are reversed in direction and position.

Type-series.—Dextral No. M$^{1\,2\,1\,2\,5}$, Sinistral No. M$^{1\,2\,1\,2\,4}$.

Measurements of shells (in millimeters).

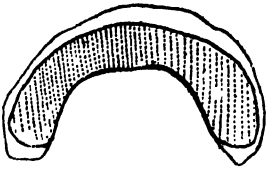
	Sinistral.			Dextral.		
	1	2	3	1	2	3
Height	21·3	21·0	20·5	18·8	17·0	17·8
Greatest breadth	6·5	7·0	7·0	6·0	6·2	6·5
Height of aperture	6·8	7·5	7·1	6·1	6·1	6·0
Breadth of aperture	4·8	5·3	5·2	4·9	4·3	4·1
Number of whorls	8¼	9	8¼	8¼	8¼	8¼

Theobald's specimens are labelled "Salt Range." Those collected by Dr. Hora are from Kallar Kahar, Sardhi, Katas and Chalisa, all places in the same range and in the Jhelum district of the Punjab. Many of the specimens from Kallar Kahar were taken alive. They were attached in large numbers to tree-trunks in an apparently comatose condition, but we can see no trace of an epiphragm.

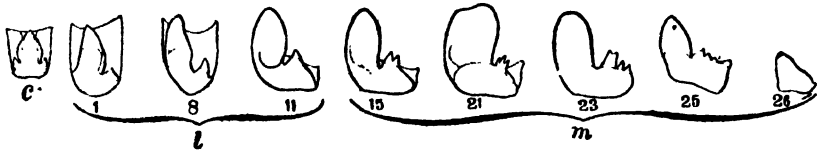
We have already suggested that local differences occur in the proportionate number of dextral and sinistral shells. The following are the facts on which we rely :—

In Theobald's series, the precise find-spot of which is unknown, the 22 specimens are all dextral. Combining this series with those obtained by Dr. Hora we have examined 154 shells. Of these 97 are sinistral and 57 dextral. In the total number, therefore, about 63 per cent are sinistral. If, however, we take the members of the series from different localities separately we find very different results. Of 48 shells from Sardhi 46 are sinistral and only 2 dextral, giving a percentage of nearly 94 per cent sinistral, while of 12 shells from Katas only 2 are sinistral, giving a percentage of only a little over 16 per cent. In a series of 70 shells from Kallar Kahar 49 are sinistral and 21 dextral, giving a percentage of about 70 per cent sinistral. Two shells from Chalisa station in the plains at the base of the range are both dextral. These shells are "dead" and may have been brought down from the hills in a flood.

We have to thank Professor P. C. Mahalanobis of the Calcutta Presidency College for the note on the mathematical significance of these figures printed immediately after this paper. His investigation seems to prove that the difference in the proportionate numbers of dextral and sinistral shells in different localities is not merely apparent.



(3)



(4)

TEXT FIG. 3.—Jaw of *Bulimus dextrosinister*, sp. nov.

TEXT FIG. 4.—Radular teeth of *Bulimus dextrosinister*, sp nov.
c. Central; *l*. laterals; *m*. marginals.

Pupoides coenopictus (Hutton).

1914. *Pupoides coenopictus*, Gude, *op. cit.*, p. 259.

Two "dead" shells were obtained by Dr. Hora at Chalisa station. Others from Theobald's Salt Range collection are in the Museum.

Pupoides lardeus (Pfeiffer).

1855. *Bulimus lardeus*, Pfeiffer, *Mart. Chem. Conch. Cab., Achatina* I, p. 151, pl. xxxix, figs. 14—16.

1876. *Bulimus coenopictus*, Hanley and Theobald *nec* Hutton, *Conch Ind.*, pl xxiii, fig. 9.

1914. *Pupoides lardeus*, Gude, *op. cit.*, p. 261.

There has been confusion about this species, Gude (*op. cit.*) cites Hanley and Theobald's figure in the synonymy of *P. coenopictus*, but these authors state that they consider the types of *P. lardeus* to belong to *P. coenopictus* and their figure agrees with Pfeiffer's figure of the former species rather than with specimens of the true *coenopictus* from Quetta, from Hutton's collection and probably identified by him. We take it, therefore, that Hanley and Theobald did not figure the true *coenopictus*.

A single fresh specimen was obtained by Dr. Hora on the banks of the Katas nallah. The specimens from the Salt Range recorded by Nevill in his "Hand List" as *Pupa* (*Leuchochila*) sp. probably belonged to this species, but we have been unable to find them.

No precise locality seems to have been assigned to *P. lardeus* hitherto. It may be endemic in the Salt Range.

Opeas gracile (Hutton).

1914. *Opeas gracile*, Gude, *op. cit.*, p. 355.

A single empty shell was obtained by Dr. Hora at Chalisa station in the plains at the base of the Salt Range.

Zootecus insularis (Ehrenberg).

1906. *Zootecus insularis*, Pilsbry in Tryon's *Man. Conch.* (2) XVIII, p. 106, pl. xxvi, fig. 21.

1914. *Zootecus insularis*, Gude, *op cit.*, p. 367.

Shells from the Salt Range are all white and opaque, but none seem to be quite fresh. They exhibit an extraordinary individual variability apparently not correlated in any way with locality. This is clearly shown by the series of measurements given below and in our figures. They were taken on fully formed specimens from two localities, namely, Sardhi on the hills, and Chalisa station in the plains at their base, both in the Salt Range, Punjab.

Dr. Hora also obtained specimens at Katas nallah.

Sardhi.			Chalisa.		
Height of shell in mm.	Greatest diameter of shell in mm.	Number of whorls.	Height of shell in mm.	Greatest diameter of shell in mm.	Number of whorls.
14·5	4·8	9⅓	15·0	5·0	9½
14·0	5·0	9	14·1	5·1	9
14·0	4·9	8½	13·5	5·0	8¾
12·6	4·3	8⅓	13·0	4·8	9
12·0	4·0	9	12·3	4·8	8¼
11·1	4·2	8¼	11·4	5·0	7¾
11·0	4·5	8½	11·2	4·9	8
10·0	4·3	8	10·7	4·4	8¼
10·0	4·2	8¼	10·5	4·6	7⅝
9·8	4·0	8	10·3	4·8	7¾
9·7	4·3	8	10·2	4·5	8¼
9·5	4·4	8	9·4	4·9	7
8·9	4·0	7¾	9·4	4·0	8
8·8	4·2	7¾	8·5	3·8	7½
8·8	4·0	7½	8·1	4·0	8

In one specimen the epiphragm remained complete. It had the form of a thin calcareous plate occupying the extreme outer part of the mouth and somewhat convex externally. Towards the upper extremity there was an elongate transverse hole. Further into the shell there were at least two similar plates separated by short intervals, both with similar holes. The soft parts had completely disappeared but we extracted an embryonic shell. Possibly the hole had been made by some enemy which had devoured the snail.

Succinea crassinuclea, Pfeiffer.

1878. *Succinea crassiuscula*, Nevill, *op. cit.*, p. 212.
1914. *Succinea crassinuclea*, Gude, *op. cit.*, p. 453.

The specimens recorded by Nevill from the Salt Range under the name *Succinea crassiuscula* are still in the collection.

The species occurs at Simla as well as in the localities recorded in the works cited above.

AQUATIC SPECIES.

Gastropoda.

Amnicola (Alocinma) pulchella (Stoliczka).

1836. *Paludina pulchella*, Benson, *Journ. Asiat. Soc., Bengal*, V, p. 746.
1876. *Bythinia pulchella*, Hanley & Theobald, *op. cit.*, p. 18, pl. xxxviii, figs. 5, 6.
1922. ? *Digoniostoma pulchella*, Baini Prashad, *Rec. Ind. Mus.*, XXIV, p. 17

This species is a true *Alocinma*, but the structure of the operculum is very liable to be obscured by erosion or the deposit of extraneous matter. The specimens from Manipur recorded under this specific name by Annandale[1] belong to the genus *Digoniostoma* as stated, but not to Stoliczka's species.

[1] *Rec. Ind. Mus.*, XXII, p. 541 (1921).

Theobald obtained shells in the Salt Range and Dr. Hora collected a large series of living specimens in a small stream at Watli as well as empty shells from Katas nallah and Chalisa. The shells are large and well formed.

Melanoides flavidus (Nevill), Annandale and Prashad.

1919. *Melanoides pyramis* var. *flavida*, Annandale & Prashad, *Rec. Ind. Mus.*, XVIII, pp. 29, 30, 34, figs. 3b, 4d, pl. iii, fig. 6, pl. iv, fig. 6.

The shape of the mouth of the shell in this form is so distinct that we prefer to regard it as a separate species. The columella is considerably longer and less arcned than in the forms we leave in *M. pyramis* and its callus is thicker and more porcellaneous. The base of the body-whorl recedes much more abruptly on the ventral surface and the outer lip projects far beyond the level of the columella. The form *luteomarginatus* has the same characters and must be regarded as a variety of *flavidus*.

Many of the shells collected by Dr. Hora in the Salt Range are quite typical. Others are larger than any hitherto measured and of an almost uniform dull olivaceous colour. Unicolorous specimens of smaller size also occur together with typical shells. The largest in the collection is 38 mm. long by 13 mm. in maximum transverse diameter. Its apex is slightly eroded.

Dr. Hora obtained living specimens in the Katas nallah, in a small stream at Shivganga and at Choa Saidan Shah.

The species has been known hitherto only from the desert region of southern Baluchistan, from S. Seistan and from Iraq.

Limnaea acuminata Lamarck.

1921. *Limnaea acuminata*, Annandale & Prashad, *Rec. Ind. Mus.*, XXII, pp. 568, 569, fig. 12.

Shells from the Salt Range are mostly typical, showing considerable variation in shape, but not quite to the same extent as the series from the United Provinces figured in the paper cited. None are of very large size and some are distinctly dwarfed, but none exhibit any marked abnormality in form or structure.

Specimens taken among algae and weeds growing on a rocky bottom in the Katas nallah have moderately thin shells of a pale luteous colour and not exceeding 26 mm. in length and 15 mm. in maximum transverse diameter. Those from Shivganga are similar. Shells from the banks of a stream at Choa Saidan Shah are slightly thicker and broader in proportion, while those from another stream at Dheri Jaba are very small, thin and rather narrow, not longer than 15 mm. or broader than 6·5 mm. Dr. Hora noted that a mineral deposit of the nature of tufa was being formed on the bottom of this stream.

Limnaea luteola Lamarck.

1921. *Limnaea luteola*, Annandale & Prashad, *op. cit.*, p. 566.

Distinct as are extreme forms of this species from those of *L. acuminata*, many shells appear to be intermediate, and we have not been able to find any constant difference in the radula or the soft parts. Indeed these structures seem to be almost as liable to variation as the shell.

Dr. Hora obtained a good series of specimens from a stream near Kallar Kahar.

Limnaea persica Issel.

1919. *Limnaea persica*, Annandale & Prashad, *Rec. Ind. Mus.*, XVIII, p. 41, pl. v, figs. 3—6.

Hitherto recorded only from Southern Persia and the Baluch desert, this species appears to have a wide range in the Himalayas and beyond. We find numerous specimens in the collection from Peshawar, from Bhim Tal and Naini Tal (4,500—7,000 feet) in Kumaon and also from Secunderabad in the Deccan. Specimens from Kumaon and from Secunderabad have been confused with *L. acuminata*, with shells of which they were mixed.

Dr. Hora obtained two living shells from a stream near Dheri Jaba and a few dead shells on the banks of the Katas nallah.

Indoplanorbis exustus (Deshayes).

1921. *Planorbis exustus*, Germain, *Rec. Ind. Mus.*, XXI, pp. 26, etc., figs. 1–16
1923. *Indoplanorbis exustus*, Rao, *Rec. Ind. Mus.*, XXV, pp. 199—219, many text-figs.

Specimens from the Salt Range are of moderate size and rather pale colour, but not otherwise remarkable.

Dr. Hora found the species living in a pond near Watli and in a stream near Kallar Kahar. He also obtained empty shells at many localities in the range.

Gyraulus convexiusculus (Hutton).

Gyraulus euphraticus Mousson.

1919. *Gyraulus convexiusculus and Gyraulus euphraticus*, Annandale & Prashad, *op. cit.*, pp. 52, 40, 53, 55, figs. 5c, 5f, (*not* 5d), 7, 8a, 8b.

These two species occur together in the Salt Range as in so many other localities. Several " dead " shells of each were found on the banks of the Katas nallah.

Gyraulus saltensis Germain.

1922. *Gyraulus saltensis*, Germain, *op. cit.*, p. 127.

We assign to this species with some doubt several empty shells found with those of the preceding two species on the banks of the Katas nallah. The type has not yet been returned to Calcutta and no figure has been published.

Gyraulus labiatus (Benson).

1915. *Planorbis* (*Gyraulus*) *labiatus*, Preston, *Faun. Brit. Ind., Fresh W. Moll.*, p. 119, fig. 5.

Dr. Hora collected a large series of living specimens in the Katas nallah. They exhibit considerable variation in the degree to which the last whorl is deflected, but otherwise agree with Preston's figures of the type-specimen.

To judge from specimens recently examined by us, *G. labiatus* is widely distributed in northern and central India.

PELECYPODA.

We are obliged to Dr. Baini Prashad for the following note on the bivalves collected by Dr. Hora in the Salt Range :—

1. The Unionidae from Choa Saidan Sahah, Salt Range and Katas nallah (Sta. 4) are all dead shells of the very widely distributed *Indonaia caeruleus* (Lea). There is no complete shell but only stray valves of different specimens.
2. The Cyrenidae from Katas nallah (Sta. 4) and Jhelum district, are all either young or highly worn shells of the common species *Cosbicula striatella* Desh., which is also a very widely distributed species.

EXPLANATION OF PLATE IX.

Eulota pentepotamiensis, sp. nov.

Figs. 1, 1*a*, 1*b*.—Type-specimen, × 2.
Figs. 2, 2*a*.—Shell with elevated spire and narrow umbilicus, × 2.
Figs. 3, 3*a*.—Shell with relatively depressed spire and broad umbilicus × 2.

Buliminus salsicola (Benson).

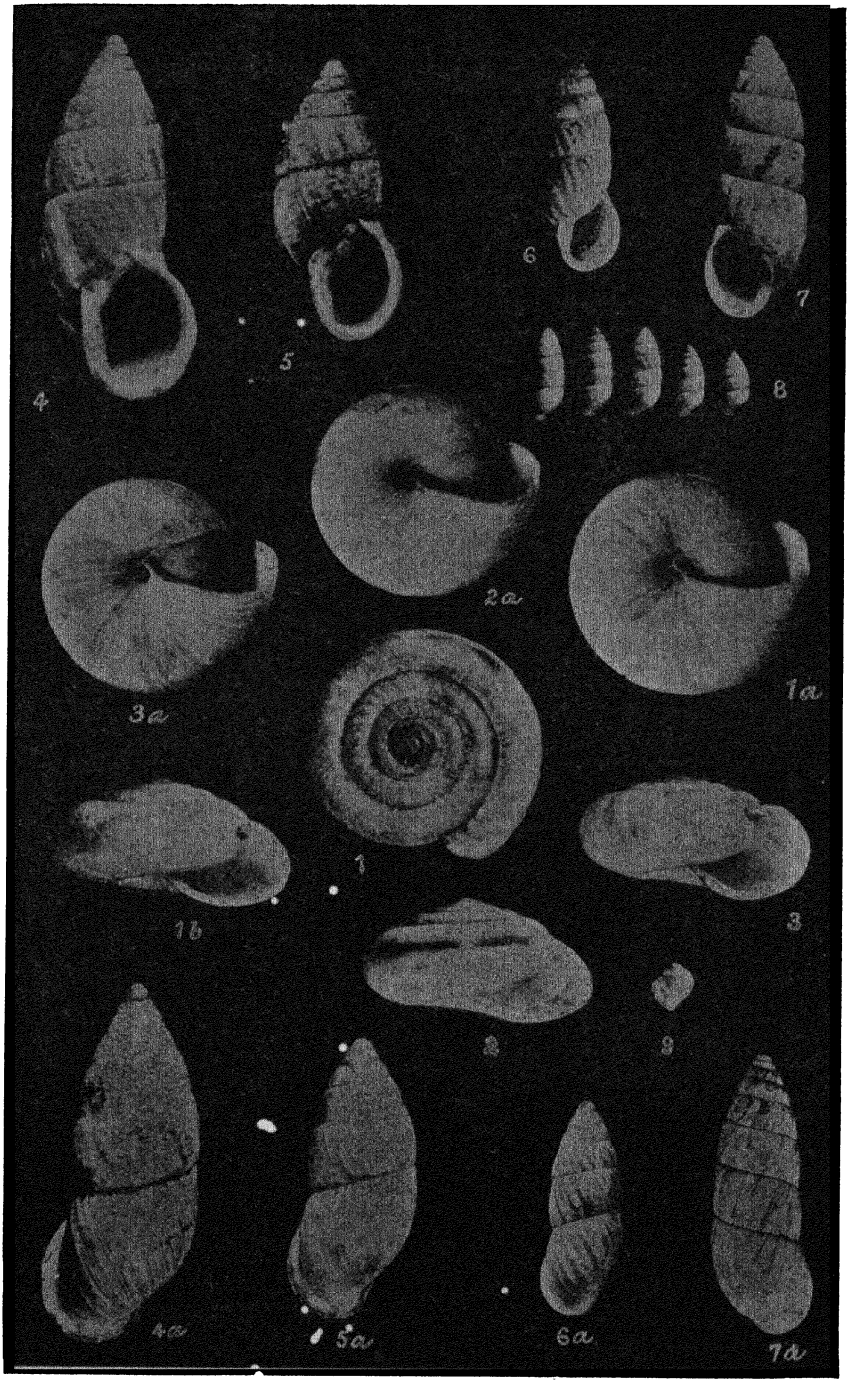
Figs. 4, 4*a*, 5, 5*a*.—Lectotypes, × 2.

Buliminus dextrosinister, sp. nov.

Figs. 6, 6*a*.—Dextral shell, × 2.
Figs. 7, 7*a*.—Sinistral shell, × 2.
} Type-specimens.

Zootecus insularis (Ehrenberg).

Fig. 8.—Adult shells from the Salt Range, illustrating variability (nat-size).
Fig. 9.—Embryo, × 4.



Salt Range Shells.

FURTHER OBSERVATIONS ON THE MOLLUSCS OF THE PUNJAB SALT RANGE

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

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

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

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

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

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

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

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

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

Bensonia jacquemonti (von Martens).

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

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

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

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

FURTHER OBSERVATIONS ON THE AQUATIC GASTROPODS OF THE INLÉ WATERSHED

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[Nearly six years ago I published an account of the aquatic molluscs of the Inlé Lake and connected waters. My paper was based on collections made early in 1917 by Dr. F. H. Gravely and myself. The results were so interesting, and cast so much light on general problems of mollusc-ecology and evolution, that I arranged to pay a second visit to the same country in March, 1922. I was accompanied by Dr. Sunder Lal Hora, Assistant Superintendent, Mr. H. Srinivasa Rao, Research Assistant, and Babu D. N. Bagchi, Artist, in the Zoological Survey of India. To these gentlemen, and especially to Dr. Hora, my best thanks are due. Dr. Hora remained in the Southern Shan States after the rest of the party returned, and made valuable additional collections. Babu D. N. Bagchi's sketches of living molluscs have proved of great value.

The main object of our expedition was to obtain further information about the remarkable genus *Taia*, and especially about its extraordinary variability and plasticity. This investigation was part of one of wider scope on shell-sculpture in the Viviparidae,[1] but the genus will be discussed merely from a taxonomic point of view in this paper. In the course of our work on special lines we obtained much additional information about the molluscs, recent and extinct, of the district, and I was so fortunate as to be accompanied for some time by Mr. F. W. Walker of the Geological Survey of India, to whose assistance I owed much in studying the various deposits of the He-Ho plain and the Hsin Dawng caves. I have to thank Dr. L. L. Fermor, who was acting as Director, Geological Survey of India, at the time, for permitting Mr. Walker to accompany our party. More frequent co-operation of the kind between the scientific departments of the Government of India seems to me highly desirable. *N.A.*]

No less than 34 species and 10 subspecies of true aquatic molluscs and 2 species of semi-aquatic habits were taken on the two visits to the Inlé watershed. Of these, 7 species and 2 subspecies appear to be extinct and were found in a fossil or subfossil condition. No less than 23 species and 7 subspecies appear to be endemic in the watershed. Of these, 7 species and 2 subspecies were only found subfossil. In this paper we describe 6 new species and 3 subspecies as new, but several of these were obtained on the former visit, but for various reasons were not given names.

The recent specimens collected on the second visit are from all parts of the Inlé watershed except the river which flows out from the south end of the lake. The area they represent extends from Kalaw and Loi-an near the head waters of the Kalaw River, which enters the lake on the western side, to Taunggyi on the hills above its north-eastern extremity, and from the valley north of the lake to Nanpan close to the point at which the southern river emerges.

The fossil and subfossil specimens are from four different deposits, three of which lie in the He-Ho plain west of the lake, while the third is on the slopes of a little valley to the north-east of Yanghwe. These four deposits have already been described elsewhere,[2] but the much

[1] Annandale, *Proc. Roy. Soc.*, XCVI, pp. 60–76 (1924).
[2] Annandale, *Rec. Geol. Surv., Ind.*, L, p. 215.

richer collection made in 1922 renders it possible to discuss the shells found in them more fully than heretofore. Those from the peaty superficial deposit on the He-Ho plain prove on more detailed comparison to be identical with the living molluscs of the valley. The deposit is in places almost incredibly rich in shells of *Taia naticoides* race *intermedia*, and the little streams that traverse it have their beds covered with shells washed out from it in a profusion rarely seen except on the sea-shore.

This is also true of the deeper lacustrine deposit of clay at the east end of the valley just above the gorge. The race of *Taia* represented in it is, however, slightly different though specifically the same. We call it *T. naticoides* race *lacustris*. The race *distoma* of *Hydrobioides nassa* is also different from that found living on the plain, and this is probably true of that of *Limnaea shanensis*, which is the typical form of the species, differing in minor characters from the race *superstes* which survives in the Inlé Lake. There are, however, two races or phases of this species in the deposit next to be discussed and their geological relations are not quite clear, though both are distinct from the living form. On the other hand *Acrostoma elongatum* from all deposits is identical with the living form.

The curious bank of calcareous particles at the head of the He-Ho gorge, exactly resembling a sand-bank in appearance, is remarkable for the large number of minute and fragile shells which it contains in a perfect condition. Among those found in it in 1922 were several hitherto not recorded from the Shan States, namely, *Ferrissia baconi* (a widely distributed form), *Limnaea laticallosa* (a new species discovered living at Kalaw), *Segmentina taia*, sp. nov., and *Intha capitis*, both of which survive in the Inlé valley, a new species of *Camptoceras*, *Succinea godivariana*, a probably amphibious species hitherto recorded only from Peninsular India, *Tricula horae*, sp. nov. and *Hydrobioides diperistoma*, sp. nov., which was formerly confused with *H. turrita*, the type-species of the genus. Both *Limnaea shanensis typica* and another form we call *L. shanensis* f. *hehoensis* occur in this deposit, the shells, in which are evidently of mixed origin, some washed out of the superficial peaty deposit of the plain, others from the old lacustrine deposit and yet others of recent origin.

The cave-deposits in the two little limestone caves at Hsin-Dawng were also revisited and the same species found in them, with the addition of imperfect shells evidently representing forms of *Acrostoma elongatum* and the remains of a freshwater crab. The three species of *Taia* already recorded (*viz.*, *T. obesa*, *T. conica* and *T. cylindrica*) were also rediscovered, *T. obesa* much scarcer than the other two. The shells had evidently been washed into the caves mainly through holes in the roof. They occur in one cave in a fan-shaped slope of earth leading down from the former and in the other in the floor just inside the mouth.

Both in living and in comparatively recent fossil freshwater molluscs the Inlé watershed is extraordinarily rich. In spite of its small area it actually contains more species of living aquatic gastropods than the whole of the plains of the Peninsular India between Peshawar and Cape Comorin and between the Indus and the Brahmaputra, and some of the species are very abundant. No less than 29 species and forms are known to us and it may be doubted whether we have yet, in

two short visits, completely exhausted the fauna. In the following list those species and races only known in a fossil or subfossil condition are marked with an asterisk: forms only known from the Inlé watershed by a dagger:—

Pulmonata.

Succinea indica Pfeiffer.
S. godwariana Gude.
*† *Limnaea shanensis* Annandale.
† *L. shanensis* f. *superstes*, nov.
*† *L. shanensis* f. *hehoensis*, nov.
† *L. mimetica* Annandale.
L. luteola f. *siamensis* Sowerby.
† *L. laticallosa*, sp. nov.
L. andersoniana Nevill.
† *L. physcus*, sp. nov.
Indoplanorbis exustus (Deshayes).
Gyraulus euphraticus Mousson.
G. labiatus (Benson).
† *G. velifer* (Annandale).
† *Intha capitis* Annandale.
Segmentina caenosus (Benson).
† *S. taia*, sp. nov.
*† *Camptoceras*, sp. nov.
Ferrissia baconi (Bourg).

Prosobranchia.

*† *Tricula horae*, sp. nov.
*† *Hydrobioides diperistoma*, sp. nov.
H. nassa (Theob.).
H. nassa f. *ararix* Annandale.
† *H. nassa* f. *lacustris* Annandale.
† *H. nana* Annandale.
† *H. nassa* f. *rivulicola* Annandale.
† *Paranerita physcus* (Annandale).
† *Amnicola alticola* Annandale.
Melanoides tuberculatus (Muller).
M. scaber (Muller).
† *Acrostoma elongatum* (Annandale).
† *A. elongatum* f. *planicostata*, nov.
A. variabile (Benson).
† *Vivipara heliciformis* (Frauenfeld).
Lecythoconcha lecythis (Benson).
† *Taia theobaldi* (Kobelt).
† *Taia naticoides* race *intermedia* Annandale.
*† *T. naticoides* race *lacustris* Annandale
† *T. shanensis* (Kobelt).
*† *T. obesa* Annandale.
† *T. crassicallosa*, sp. nov.
*† *T. conica* Annandale.
*† *T. cylindrica* Annandale.
† *T. elitoralis* Annandale.
† *T. intha* Annandale.
Pila conica var. *compacta* (Reeve).

Genus **Limnaea** (*auctorum*).

The genus is remarkably well represented in the He-Ho plain and the Inlé watershed, for no less than six living species have been found in this area, whereas only three are known from the whole of Peninsular India if we exclude the Punjab Salt Range into which certain Palæarctic forms intrude. These six species, however, are quite distinct and most of them are not at all closely related the one to the other.

The *Limnaea*-fauna of this district exhibits affinities both with that of Peninsular India and with that of Indo-China. Of the six species one represented by a Burmese and Siamese race is conspecific with a common Indian mollusc. This is *L. luteola* f. *siamensis*. The race occurs both in Upper and in Lower Burma and also in Tenasserim. Four species are known only from the district under discussion, viz., *L. physcus* and *L. laticallosa*, both described here for the first time, *L. mimetica*, a true lacustrine form from the lake, and *L. shanensis*, the typical form of which is apparently extinct, but is represented in the living fauna by the race *superstes*. Finally, *L. andersoniana* has a range that extends from Western China through the hill country of Burma to Manipur in Assam on the one hand and the Nepal Himalayas and Kashgar in Central Asia on the other. This species is closely allied to the Palæarctic, *L. truncatula*.

Key to the species of Limnaea known from the Shan Plateau.

1. Columellar fold exceptionally broad and coarse, occluding the umbilicus on the ventral surface of the shell. Umbilicus often visible from the dorsal surface.
   - A. Shell not exceeding 16 mm. in length with 5 whorls, very variable in shape ... ... *L. andersoniana.*
   - B. Shell over 16 mm. long, with 6 whorls, of a regular narrowly ovate form ... ... *L. laticallosa.*
2. Columellar fold normally developed. Umbilicus never visible on the dorsal surface.
   - A. Spire not depressed, almost or quite as high as broad. Body-whorl much narrower, but not tapering in front ... ... *L. physcus.*
   - B. Spire not depressed at the base, more than twice as broad. Body-whorl much narrower but not tapering in front.
     - (i) Columellar callus narrow Spire situated asymmetrically towards the left side of the body-whorl, which is oblique,
       - (*a*) Spire much reduced, blunt at the apex, shell not more than 7 mm. long, colourless, very fragile ... ... *L. mimetica*
       - (*b*) Spire sharply pointed, short but well developed. Shell at least 9 mm. long, coloured, less fragile ... ... *L. shanensis.*
     - (ii) Columellar callus broad. Spire situated symmetrically on the middle of the body-whorl, which is not at all very oblique. Whole shell of a narrowly oval form ... ... *L. luteola* f. *siamensis.*

Limnaea physcus, sp. nov.

1918. *Limnaea* ? prox. *oralis*, Annandale, *op. cit.*, p. 111.

Two living specimens, one adult and one young, of a species, apparently identical with the fossil or subfossil form cited above were discovered by Dr. Sunder Lal Hora in a railway reservoir near He-Ho. They are more globose than that form, but otherwise agree with it, so far as can be seen in the imperfect condition of the fossil shells. The species seems to be quite distinct and may be defined as follows :—

Shell small, cordiform, with a very small, sharp spire, delicate, transparent, horn-coloured, decorated with fine longitudinal striae, without spiral sculpture, with an oily lustre, Spire consisting of $2\frac{1}{2}$ short transverse whorls, minut ly and obliquely truncate at the apex ; the whorls not at all swollen, with their outlines almost straight but sloping outwards, the second at least three times as long as the apical comp lete whorl, much narrower than the upper extremity of the body-whorl and situated towards its inner margin ; the suture moderately impressed. The body-whorl relatively very large, oblique, tapering in front to a blunt point, with the outer margin as seen in dorsal view forming a regular curve of less than a semi circle and the inner margin strongly sinuate ; the dorsal surface highly convex. The aperture very large but not expanded, auriculate, pointed and introverted above, narrowly rounded below, The columella twisted and curved ; its

callus delicate but rather broad completely occluding the umbilicus, meeting the outer lip above. The outer lip curved, very delicate. The ventral surface of the whorl highly convex in its upper half.

Owing to an accident the soft parts of the only adult recent specimen were destroyed. The shell occurs very rarely in the lacustrine deposit of clay on the banks of the He-Ho river and was not found in the sandy mud at the head of the gorge, probably on account of its fragility which would render its transport in the river difficult and improbable.

Measurements (in millimeters) of type-specimen.

Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.
8·4	7·2	6·5	4·2

Type-specimen—No. M. $\frac{12045}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

The species seems to be allied to some of the Palæarctic forms of the *peregra* group, but is very distinct from any Indian form hitherto described.

The species is only known at present from the He-Ho plain (alt. 3,800 ft.) in the Southern Shan States.

Limnaea laticallosa, sp. nov.

This is a species resembling the stream form of *L. andersoniana*[1].

But with a larger shell, more numerous whorls, a still better developed columellar fold, a distinct flattening of the whorls outside the suture and less numerous radular teeth. It also appears to be related to *L. crosseana*[2] from Cambodia and Tonquin and resembles some specimens of that species more closely than it does the original figure, but has the shell thicker, the columellar fold and callus much better developed, the mouth of the shell more expanded on the outer side, the umbilicus open on the dorsal surface (though occluded on the ventral) and the sculpture much better developed.

The shell is of moderate size, somewhat elongate and rather narrow, sharply acuminate to the naked eye, moderately thin, translucent, of a horny brown colour and sculptured with irregular longitudinal striae interrupted at intervals by spiral decussate lines, with an oily lustre on the surface.

The shape is narrowly ovate with the spire well exerted, comparatively long, placed vertically on the middle of the body-whorl and occupy from about $\frac{1}{3}$ to nearly a $\frac{1}{2}$ of the length of the shell. There are six complete whorls; they increase gradually and evenly in size. The suture is impressed and a little oblique, especially on the dorsal surface. The upper extremities of the whorls are narrowly and slightly, obliquely flattened outside it much as in the shell of *L. truncatula*. The body-whorl is distinctly spiral and the umbilicus or rather a channel leading to it, is visible on the dorsal surface in the form

[1] Annandale & Prashad, *Rec. Ind. Mus.*, XXII, p. 576, pl. viii, figs. 4, 5 (1921).
[2] Mabille and le Mesle, *Journ. de conchyl.* (3), XIV, p. 130, pl. vii, fig. 5 (1866).

of a pinhole. The callus and the columellar fold cover a considerable part of the ventral surface of the body-whorl and are coarse, longitudinally striate and lustrous. The columella is strongly twisted and almost vertical. The outer lip is thin and has a somewhat flattened curve. It is not at all introverted above. The aperture as a whole has a distinctly auriculate form and is somewhat dilated outwards below; above it is sharply pointed. The peristome is complete.

Measurements (in millimeters) of type-specimen.

Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.
15·7	9·7	8·4	4·9

The jaw is very characteristic. The maxilla is narrowly biconvex with a transverse ridge in the middle, and the lateral pieces are long and tapering and distinctly fimbriate on the inner surface.

The radula is also very characteristic. The cusps of all the teeth are remarkably long and narrow, especially as regards the mesocone. Some of the laterals are bicuspid but the first is always tricuspid. The peculiar shape of the teeth is shown in the figure. The approximate dental formula is 19. 8. 1. 8. 19.

The genitalia offer no very striking peculiarity. In two specimens examined the spermatheca is remarkably large and of subtriangular outline. Its duct is long and somewhat swollen just before entering the sac. In these specimens the penis is very slender and the prostate small and heart-shaped.

The animal (in spirit) is of a leaden grey colour, with the tentacles broadly triangular and the anal funnel exceptionally prominent.

Type-specimens.—No. M. $\frac{12055}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

A large series of shells and specimens in spirit was obtained by Dr. Hora from a small reservoir used for horticulture above Kalaw[1] at an altitude of about 4,500 ft. The water was clear, the bottom muddy; there were no water plants.

Limnaea luteola Lamarck.

This is one of the commonest and most widely distributed of the Indian species, but several forms can be distinguished. The common Burmese race, for the study of which abundant material is before us from Tenasserim, Pegu, Upper Burma and the Southern Shan States, is evidently identical with Sowerby's *L. siamensis*. In India and Ceylon at least four forms may be distinguished if sufficient material be examined, but only two of these can be regarded as well established races, namely the *forma typica* (with its phases or varieties *succinea* Deshayes and *impura* Troschel) in India and the subspecie *australis*, nov. in Ceylon and parts of Peninsular India. Specimen from Kulu in the Western Himalayas are quite typical. Nevile

[1] Kalaw is situated some little distance west of the He-Ho plain on a small stream that ultimately flows into the Inlé Lake after proceeding some miles underground.

recognized the Burmese form as a distinct variety but did not give it a name. The five forms may be distinguished as follows :—

I. Length of shell usually more than 20 mm., shell somewhat elongate with the body-whorl subcylindrical and a little compressed—	
A Shell with pale longitudinal stripes moderately thin	*Forma typica.*
B. Shell pale, without longitudinal stripes, thin.	*Succinea*
II. Shell less than 20 mm.. in length : body-whorl not subcylindrical.	
A. Shell rather short, ovate	*Impura.*
B. Shell more elongate.	
(i) Body-whorl bilaterally a symmetrical in ventral view	*Australis*[1].
(ii) Body whorl almost bilaterally symmetrical	*Siamensis.*

Race **siamensis** Sowerby.

1873. *Limnaea siamensis* Sowerby in Reeve, *op. cit.*, sp 63, pl. x.
1878 *Limnaeus luteolus* var. Nevill, *Hand List Moll. Ind. Mus*, I. p. 233.

The most characteristic feature of this race is noted in the key. The shell never exceeds 16 mm. in length and is usually about 1½ times as high as broad. It differs greatly in colour and thickness in different localities and types of environment. Specimens from the Royal Lakes in Rangoon are small, with thin, pale lutescent shells : but Dr. Marshall has sent from the same city a much brighter rather larger and thicker specimen. Those obtained from a muddy pool used for domestic purposes at He-Ho are thicker and have a solid appearance. The natural colour is dull lutescent, but there is a thin black deposit on the surface and the spire is eroded.

The animal is always rather dark. The tentacles are large and triangular ; the lips normal, the oval funnel is exceptionally well developed. It will be better to defer any description of the anatomy until a comparative account of the soft parts of the different races can be prepared. The radular formula is approximatoly 16. 7. 1. 7. 16.

This form provides a link (both geographical and structural) with the Malayan *L. javanica.* The shell, however, differs in that the body-whorl is always narrow, with the aperture less dilated, and the spire relatively broader and not so tapering.

Family PLANORBIDAE.

Subfamily **Planorbinae.**

1922. *Planorbinae*, Annandale, *Rec. Ind. Mus.*, XXIV, p. 358.

Like the Limnaeidae this subfamily is also represented by several species in our recent collection. All but one of these were also taken on the first visit to the Shan States, but the identifications were not correct.

Unlike the Limnaeidae, the Planorbidae offer good generic characters of an anatomical nature, and the seven species can be distributed into four genera which are well defined both on such characters and also conchologically. These four genera are *Indoplanorbis* Annandale and Prashad, *Gyraulus* Agassiz, *Segmentina* Fleming

[1] *Australis* is the name we propose for *pinguis* Dohrn, preoccupied.

and *Intha* Annandale, the last being a genus recently described from our Shan collection.

Genus **Indoplanorbis** Annandale.

1922. *Indoplanorbis*, Annandale, *Rec. Ind. Mus.*, XXIV, p. 360.

Indoplanorbis exustus (Deshayes).

1918. *Planorbis exustus*, Annandale, *Rec. Ind. Mus.*, XIV, p. 111, pl. xi, figs. 1, 1a.

1921. *Planorbis* (*Planorbis*) *exustus*, Germain, *Rec. Ind. Mus.*, XXI, p 26, figs. 1—11 and 13—16.

1923. *Indoplanorbis exustus*, Rao, *Rec. Ind. Mus.*, XXV, pp 199—219, text-figs. 1 3a, 4—7, and 9—14.

Common in the marginal zone of the Inlé Lake and also on the He-Ho plain. Shells from this district are usually of moderate size and regular form, with fine and regular sculpture and of a chestnut-brown colour.

Genus **Gyraulus** Agassiz.

1922. *Gyraulus*, Annandale, *op. cit.*, p. 361.

Gyraulus convexiusculus (Hutton).

1918. *Planorbis saigonensis* (?). Annandale *op. cit.*, p. 112, pl. xi, fig. 12.

It is to this species and not to *G. euphraticus* Mousson that shells from the sand-like deposit on the He-Ho gorge belong. A few living specimens were also taken in the marginal zone of the Inlé Lake.

Gyraulus velifer (Annandale).

1918. *Planorbis velifer*, Annandale, *op. cit.*, p. 112, pl. xi, figs. 7—11.

The species is closely allied to *G. convexiusculus* and *G. euphraticus* but differs from both in its more delicate shell, in the different shape of the mouth of the shell, which is much more expanded, in possessing a thin but distinct callous deposit on both lips and in the very pale colour of its blood [1]. It is by no means confined to the Inlé Lake as was formerly thought, but is also found in ponds and canals in other parts of the valley and subfossil in the sand-like deposit of the He-Ho gorge. The opaque subfossil shells can be recognized by their expanded mouths and by the deposit on their lips, which is particularly distinct in them owing to its polished surface. We figure the living animal from drawings made by Babu D. N. Bagchi in the Southern Shan States. Individuals from the lake are often quite colourless. Sometimes they have a black line running along each tentacle and occasionally the whole of the surface of the body is suffused with black pigment. The shell is always hyaline and colourless. Specimens from the canal at Yawnghwe are darker and their shell is usually tinted of a pale yellowish colour.

[1] See Annandale, *Rec. Ind. Mus.*, XXIV, p. 358 (1922).

As Annandale has pointed out elsewhere (*op. cit.*, 1922), the blood is slightly pinker in such individuals than in those from the lake.

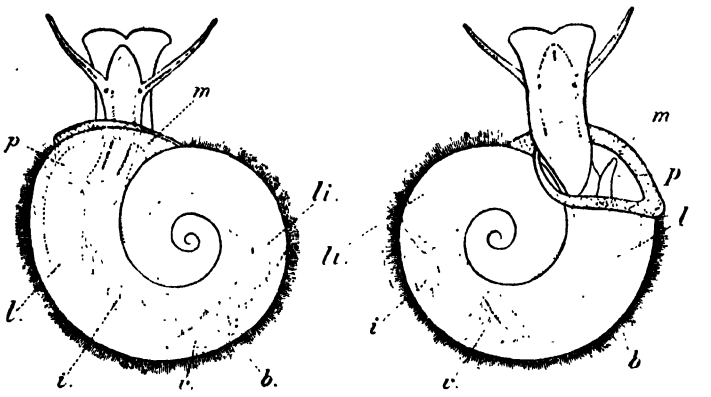


FIG. 1.—*Gyraulus velifer* (Annandale).
A. Dorsal view of living animal in an expanded state.
B. Ventral view of same.
b. bacterial velum ; *i.* intestine ; *l.* pulmonary chamber ; *li.* liver ; *m.* edge of mantle ; *p.* pseudobranch ; *r.* ventricle.

Gyraulus labiatus (Benson).

1915. *Planorbis* (*Gyraulus*) *labiatus*, Preston, *Faun. Brit. Ind.*, Freshw. Moll., p. 119, fig. 5.

Several shells from the sand-like deposit at the He-Ho gorge belong to this species. They agree exactly with the figures of Benson's types in the work cited. The whitish ridge on the inner surface of the lip is very well developed in them[1], but the departure of the last whorl from its axis is less marked than in specimens from Calcutta, Mettupalaiyam (S. India) and the Central Provinces. The Shan specimens are also smaller.

Genus **Segmentina** Fleming.

1922. *Segmentina*, Annandale, *op. cit.*, p. 362.

The two species Annandale identified in 1918 were, as we now believe, both identified incorrectly. One of them appears to be the true *Caenosus* of Benson, the other new.

Segmentina caenosus (Benson).

1876. *Planorbis caenosus*, Hanley and Theobald, *Conch. Indi.*, pl 39, figs 7-8.
1918. *Planorbis calathus*, Annandale (*nec* Benson), *op. cit.*, p. 113.

The specimens examined by Annandale in 1918 were young. The adult shell which is not uncommon in the Inlé valley and occurs sub-fossil at the He-Ho gorge, is much less transparent than that of *S. calathus*

[1] The ridge appears to be well formed in adult shells in which the growth of the lip is complete, while it varies in prominence in younger specimens.

and the internal ridges are not so well developed. In some specimens, indeed, they are difficult to detect. The size of the imbilicus is also a good character. The blood is of a much deeper red than it ever is in *Gyraulus velifer*.

Segmentina taia, sp. nov.

1918. *Planorbis caenosus*, Annandale (*nec* Benson), *op. cit.*, p. 113.

The shell is conoidal, flattened below, and concave at the apex above. The last whorl slopes abruptly towards the ventral surface. Four and a half gradually increasing whorls are seen from above. The ventral surface of the shell when seen from below though flat in appearance is slightly convex along the middle of the last whorl. The umbilicus is

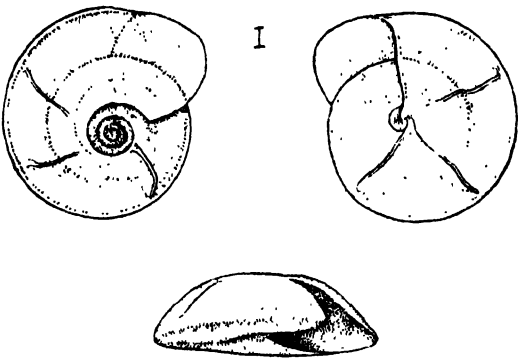


FIG. 2.—*Segmentina taia*, sp nov.

minute and occluded and is in the form of a shallow pit. The internal ridges of the shell are visible from below in adult shells, while in young shells they are seen from both surfaces. A faint fourth ridge is often visible on the side nearest to the aperture. In ventral view the aperture has a quadrate appearance while from the sides it is obliquely hastate in outline. The narrow end of the mouth never extends much beyond the level of the opposite extremity of the last whorl. The ventral margin of the peristome is almost straight and joins the strongly arched and convex dorsal margin at its outer extremity. The dorsal margin of the mouth overhangs the ventral considerably in front. The sculpture consists of fine longitudinal obique striae. The adult shell is of a yellowish brown colour, while young shells are paler.

Measurements (in millimeters) of type specimen.

Greatest diameter of shell.	Height of shell.	Greatest height of aperture.	Greatest breadth of aperture.
3·0	1·5	0·7	1·5

Anatomy [1].—The jaw consists of a single narrow chitinous strip bent in the form of an inverted U and is distinctly segmented. The radula

[1] Rao, H. S., *Rec. Ind. Mus.*, XXV, pp. 203, 205, 210, 216 and 217 (1923).

is a narrow ribbon with minute teeth. The intestine is long and surrounds the liver more or less completely. The pseudobranch is absent. The genitalia agree with those of *Gyraulus* in general structure and arrangement but differ in the absence of a bulbous swelling to the penis-sheath, and of a penial stylet.

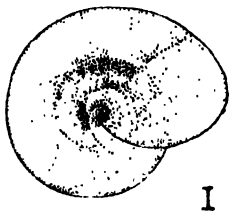
Living specimens of this species were found in the marginal zone of the western shore of the Inlé Lake and in the canal at Yawnghwe, S. Shan States. Specimens from the latter locality are smaller and paler.

This species is closely allied to *S. calathus* (Benson) from which it can be distinguished by its more pronounced conoidal form by the gradually increasing size of the whorls, by the sides of the keel forming a small angle (due to extreme flattening), by the straight lower margin of the peristome (which in *S. calathus* is concave), by its greatly arched upper margin, and by the occluded umbilicus.

Type-specimen.—M. $\frac{12461}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Intha capitis Annandale.

1918. *Planorbis trochoideus*, Annandale (*nec* Benson), *op. cit.*, p. 113.



I

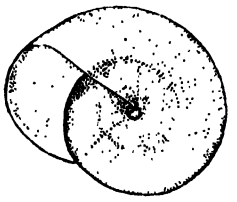




Fig. 3.—Type specimen of *Intha capitis* Annandale from Inle Lake.

Living individuals of this species occur commonly in the central and marginal zones of the Inlé Lake, and subfossil shells in the sand-like deposit on the He-Ho gorge.

A further examination of the genitalia of this minute species shows that they do not belong to type I as stated in the original description of the genus (*op. cit.*, p. 359, 1922), but agree rather with those of *Segmentina*. There are, however, no ear-like processes above the penial sheath. There is no penial stylet. Details are difficult to distinguish on account of the minute size of the structures and the highly contracted state of the material examined.

This species is named after Mr. W. R. Head, Assistant Superintendent, Yawnghwe, in 1922, to whom we were greatly indebted for much assistance during our tour in the Yawnghwe State.

Genus **Camptoceras** Benson.

1922. *Camptoceras*, Annandale, *op. cit.*, p. 363

Camptoceras sp.

Several specimens of a new species allied to *C. terebra* were found in the granular calcareous deposit on the He-Ho gorge. They have been submitted to Dr. Germain for description.

Fam. ANCYLIDAE.

Genus **Ferrissia** Walker.

In their recent revision of the Indian Ancylidae [1] Annandale and Prashad treated *Ferrissia* as a subgenus of *Ancylus*, and we still believe that they were right in doing so on theoretical grounds ; but a practical objection arises owing to the difficulty of deciding what will finally be accepted as the type species of *Ancylus*. We are in full agreement with those who claim that two distinct genera are represented by the two British species of the family (*lacustris* and *fluviatilis*) but which should be regarded as a genotype of *Ancylus* is another matter, which we leave to the experts on nomenclature to discuss. We therefore accept *Ferrissia* as a genus pending final agreement on this point, merely claiming its very close relationship to "*Ancylus*."

Ferrissia baconi (Bourg).

1921. *Ancylus* (*Ferrissia*) *baconi*, Annandale and Prashad, *Rec. Ind. Mus.*, XXII. p. 592.

Several shells were found in the sand-like deposit at the head of the He-Ho gorge. The range of the species is believed to extend from Bengal to Japan.

Fam. RISSOIDAE.

Genus **Hydrobioides** Nevill.

1884. *Hydrobioides* (subgenus of *Bithynia*), Nevill, *Hand List Moll. Ind. Mus.* II. p. 42.
1918. *Hydrobioides*, Annandale, *op. cit.*, p. 117.
1924. *Hydrobioides*, Annandale, *Proc. Mal. Soc. London*, XVI, p. 28.

As former descriptions of the genus have proved inadequate for its recognition, a more detailed diagnosis is necessary.

The shell of the genus is always rather thick and of a narrowly ovate or turrited form. It is of small or moderate size. The umbilicus is closed or almost so and there is no channel leading downwards from it towards the lip. The lip itself is thickened near the margin, but the actual margin is usually somewhat attenuate, the thickening, which is often visible externally and always well developed internally, is really a kind of varix. but must not be confused with the much more prominent varix that often occurs above it. In addition to being attenuate the lip is more or less expanded outwards in its lower part. The outer thickening forms a ridge inside the shell against which the operculum rests when withdrawn. It is only in growing shells, therefore, that the operculum can be pulled far into the aperture. The columellar callus forms a narrowly flattened and expanded fold which usually occludes the narrow umbilicus.

The operculum is thick and shelly, with a thin outer horny covering. In the very young shell its structure is distinctly paucispiral and the nucleus is situated towards the inner margin near the middle

[1] Annandale & Prashad, *Rec. Ind. Mus.*, XXII, p. 588 (1921).

point; but in the adult the spiral figure becomes obsolete and the external sculpture is concentric, while the internal surface is smooth.

The anatomy is very similar to that of *Bithynia*.

Hydrobioides differs from *Amnicola* in the structure of the lip, the operculum (vide pl. xiv, *Rec. Ind. Mus.*, XIV, 1918) and of the male organ [1]; from *Digoniostoma*, to which it is closely allied, the chief difference lies in the structure of the mouth of the shell. In the former genus the lip is not so much thickened, the umbilicus is usually more open and is always connected with a channel that runs on the surface of the shell obliquely downwards towards the lip, while the callus is narrow and more ridge-like.

Annandale [2] has recently proposed a division of *Hydrobioides* into two subgenera, viz., *Hydrobioides* s.s. and *Parafossarulus*. The latter, which has its headquarters in China but also occurs in Burma, has no varix on the lip and is sometimes ornamented with spiral shell-sculpture.

Subgenus **Hydrobioides** Nevill.

Hydrobioides diperistoma sp. nov.

1918. *Hydrobioides turrita*, Annandale (*nec* Blanford), *op. cit.*, p. 117.

The shell is small and thick with the spire conical, slightly longer than the inner margin of the body-whorl but much shorter than the outer margin. The body-whorl is markedly sinuate in outline and the anterior lobe as seen in dorsal view is remarkably well developed and distinct. The whorl is sub-carinate, with a blunt ridge running round the periphery. The ridge marks the termination of the inner margin of the body-whorl in dorsal view. In ventral view the true spire is half as long as the body-whorl, to the lower part of which the aperture is appended as a kind of projection. The structure of the peristome is highly peculiar, but may be taken to represent that typical of the genus in its highest development. There are indeed two peristomes. The inner of these is comparatively small, ovate and oblique. It is defined by a narrow but prominent ridge which is particularly conspicuous on the internal surface of the outer lip. This peristome, which forms the true mouth of the shell is situated within another of much larger size, less oblique and of different shape. The outer peristome is continued above the inner and is sharply pointed at the apex, leaving a distinct triangular area between the two. The lip is broadly expanded beyond the inner peristome, especially in the anterior region and is somewhat thickened. Its outer margin is a little sinuous but almost parallel to the columellar callus which is quite straight. The callus is rather



FIG. 4. - Type-specimen of *Hydrobioides diperistoma* sp. nov.

[1] Annandale & Prashad, *Rec. Ind. Mus.*, XVIII, p. 29, fig. 2.
[2] Annandale, *Proc. Mal. Soc. London*, XVI, p. 28.

broad and well developed, especially above the rimate umbilicus which is completely closed. Above it meets the outer lip without becoming narrower.

Measurements (in millimeters) of type-specimen.

Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.
5·20	2·35	3·00	1·70

Type-specimens.—M $\frac{12459}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

The double peristome of this form is much more distinct than in the true *H. turrita* (Blanford), which is figured by Nevill in *Journ. As. Soc. Bengal*, L (2), pl. vi, fig. 15.

The shells were found in large numbers in a sub-fossil condition in the deposit at the head of the He-Ho gorge. No living specimens were found.

Hydrobioides nassa (Theobald).

1918. *Hydrobioides nassa* (with subspp.) and *H. avarix*, Annandale, *op. cit.*, pp. 118, 120, pl. xiii, figs. 1—7; pl. xiv, figs. 3, 4.

Key to the phases of Hydrobioides nassa (Theobald).

1. Varix on lip of shell poorly developed ... *Avarix.*
2. Varix well developed.
   - A. Varix almost confluent with thickened edge of lip, separated merely by a narrow groove ... ... *Distoma.*
   - B. Varix separated from edge of lip by a flattened area.
     - (i) Edge of lip only slightly thickened; shell comparatively thin .. *Ruralicola.*
     - (ii) Edge of lip distinctly thickened; shell thick.
       - (*a*) Flattened area between edge of lip and varix at least 1/3 as broad as diameter of the shell. *Lacustris.*
       - (*b*) Flattened area much narrower... *Typica.*

In specimens of the form *avarix* traces of a varix close to the edge of the lip can be distinguished in a good light and in some it is fairly well developed. We found this form abundant in a warm spring the temperature of which was, at 7 o'clock in the morning, 27°C, while that of the air was 17°.6 C.

Shells of the *forma typica* have recently been presented to the Indian Museum by Mr. J. R. le B. Tomlin labelled as *Pachydrobia paradoxa* Crosse & Fischer. They are from the Mekong. The two species resemble one another so far as the shell is concerned, but the operculum, radula and male organ are very different.

Subgenus **Parafossarulus** Annandale.

1924. *Parafossarulus*, Annandale, *op. cit.*, p. 28.

Hydrobioides nana, Annandale (*op. cit.*, p. 121, pl. xiv, fig. 3, 1918) belongs to this subgenus. Shells are not uncommon in the deposit above the He-Ho gorge.

In form and colouration the animal differs somewhat from that of *H. nassa*. The foot is very narrow and tapers behind to a fine point. In front it is truncate with the lateral angles evenly rounded and not

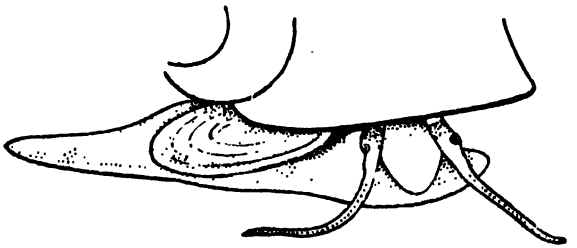


FIG. 5.—*Hydrobioides nana* Annandale. Living animal.

at all prominent. The snout is short and rather narrow and appears either bilobed or pointed in accordance with the position from which it is seen. The tentacles are very long and narrow and sharply pointed, with the minute eyes situated on them at some distance from their point of origin. The colour of the exposed parts is white or grey with a conspicuous yellow or red blotch behind each eye. The tentacles are spotted with black and the snout is sometimes infuscate.

Genus **Amnicola** Gould & Haldeman.

Subgenus **Alocinma** Annandale & Prashad.

1919. *Alocinma*, Annandale & Prashad, *Rec. Ind Mus*, XVIII, p. 23.

Amnicola alticola (Annandale).

1918. *Amnicola alticola*, Annandale, *op. cit*, p 122, pl. xiv, figs. 6, 6*a*.
1919. *Amnicola* (*alocinma*) *alticola*, Annandale & Prashad, *op. cit*., p. 24, fig. 1-B.

Genus **Paranerita** Annandale.

1920. *Paranerita*, Annandale, *Rec. Ind. Mus*., XIX, p. 45.
1921. *Paranerita*, Annandale & Prashad, *Rec. Ind Mus*., XXII, p 4.

Paranerita physcus (Annandale).

1918. *Hydrobioides physcus*. Annandale, *op. cit*., p. 121, pl. xiii, figs. 8, 8*a*, 9; pl. xiv, figs 5, 5*a*.

Genus **Tricula** Benson.

1921. *Tricula* (in part), Prashad, *Rec. Ind Mus*., XXII, p 67.
1924. *Tricula*, Annandale, *Amer. Journ. Hygiene*, Monographic Series, No. 3, p. 278.

Tricula horae sp. nov.

Shell narrowly ovate, sub-turrited with 5 to 6 whorls. Spire occupying in dorsal view a little more than half the total length. Apex blunt, mamillate. Outline of shell regular and very little broken by

the suture, which is slightly impressed and transverse, whorls of the spire increasing gradually and evenly, the lateral outlines straight and

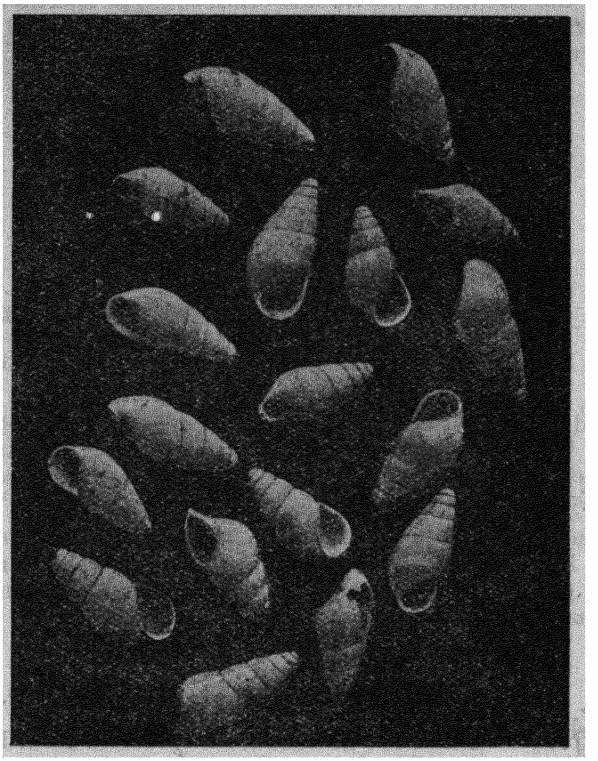


FIG. 6.—*Shells of Tricula horae*, sp. nov.

not very oblique. Body-whorl occupying nearly half the length of the shell, as seen in dorsal view with the outer margin much longer than the inner, which is evenly rounded. The anterior lobe of the shell in this view not greatly accentuated. On the ventral surface the whorl is slightly convex in its upper part with a slight indication of a peripheral keel, below which it recedes rapidly. The aperture is subtriangular and oblique, sharply pointed above and a little expanded below. The outer lip is thin but slightly callous, highly convex downwards and generally having a sinuate outline. The peristome is complete and the callus is well developed in the form of a narrowly flattened ridge continuous at the lip and completely closing the imbilicus. The interior of the mouth is finely polished. The external structure consists of faint longitudinal striae. In a subfossil state the shells have a porcellaneous appearance and sometimes retain faint traces of an olivaceous colour. The operculum has disappeared.

Measurements (in millimeters) of type-specimen.

Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.
2·78	1·05	1·10	0·69

Type-specimen.—M. $\frac{12460}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

Shells are common in the deposit at the head of the He-Ho gorge but we did not find the species alive.

From the shells of *Tricula montana*, the type species of the genus, those of *Tricula horae* are distinguished by the larger body-whorl and by the structure of the lip.

Family MELANIIDAE.

Genus **Acrostoma** Brot.

1921. *Acrostoma*, Annandale, *Rec. Ind. Mus.*, XXV, p. 509.

Acrostoma elongatum (Annandale).

1918. *Melania baccata* subsp. *elongata*, Annandale, *op. cit.*, p. 115, pl. xii, figs. 3–7.

1922. *Melania persculpta*, Ehrmann, *Sitzungsber. Natuf.-Ges.* zu Leipzig, IX, p. 18, fig. 8 in plate.

Several shells with a thick calcareous deposit were obtained in the stream at Tai-O, Yawnghwe State. The species is commonly found-living in swamps on the He-Ho plain. We also obtained several shells from a clay-pit one mile above the He-Ho gorge.

The radular teeth are not unlike those of *Acrostoma variabilis* (Benson), but the large middle cusp of the laterals is much better developed than in the latter species and the median cusp on the central is somewhat blunt.

Acrostoma elongatum f. **planicostata**, nov.

This form of which we have a recent specimen from He-Ho and a fossil shell from the Hsin Dawng Caves, is distinguished by the fact that it has well developed vertical ribs on its whorls and that the two rows of tubercles and the spiral ridges surrounding them are obsolete. Traces of the tubercles can, however, be seen in a good light. The two shells we have examined are small, that from the Hsin Dawng Cave is incomplete at the apex of the spire, while the living specimen from He-Ho is, unfortunately, broken.

The latter is paler in colour than most specimens of the species and has a well-marked spiral band of a dark brown colour running round the whorls.

We have a fossil specimen with two rows of tubercles from the Hsin Dawng Cave.

We have been able to extract the radula from the specimen obtained at He-Ho. The radular teeth do not differ from those of *Acrostoma elongatum* f. *typica*.

The species is so variable in details of sculpture (although less so in its general character than any others) that it seems unnecessary to regard *Acrostoma elongatum* f. *persculpta* Ehrmann as distinct.

The range of the species extends from the headwaters of the Kalaw stream at Loi-an through the He-Ho plain down to its entrance into the Inlé Lake on its western shore.

Melanoides tuberculatus (Muller).

1918. *Melania tuberculata*, Annandale, *op. cit.*, p. 114 & pp. 155–156, pl. xii, figs. 1–2.

Eight large shells of this species were obtained in a clay-pit one mile above the He-Ho gorge along with shells of *Acrostoma elongatum*. They are of the same size as the specimens obtained in our previous visit in a ridge of recent tufa on the He-Ho plain, and agree with the Shan species figured as *Melania pyramis* var. *adspersa* by Hanley & Theobald[1] except that the mouth is relatively small and not expanded.

Melania terebra Benson.

1918. *Melania terebra*, Annandale, *op. cit.*, p. 115, pl. xii, fig. 9.

We obtained no individuals of this species unless an incomplete smooth shell from the Hsin Dawng Cave deposit, that we took along with *A. elongatum*, represents it.

Fam. VIVIPARIDAE.

Genus **Vivipara** Montfort.

The only specimen of this genus we have from the S. Shan States is a shell of *V. heliciformis*[2] Frauenfeld collected by Dr. S. L. Hora at Kalaw near the head-waters of the stream which enters the Inlé Lake on the west side. This shell and the single specimen of *Lecythoconcha lecythis* collected in the Inlé Lake on the first visit are the only Viviparidae other than *Taia* we have seen from the Inlé system.

Genus **Taia** Annandale.

1918. *Taia*, Annandale, *op. cit.*, pp. 123, 160.
1924. *Taia*, id., *Proc. Roy. Soc. London* B, XCVI, p. 60.

One of the main objects of our visit to the Shan States in 1922 was to obtain further information about this interesting genus and a large additional collection of shells and preserved material was made.

The characteristic anatomical features of the genus are these :—

(*a*) the head of the animal is relatively larger than in *Vivipara* and has the eyes almost completely sessile ;

(*b*) the edge of the mantle is more muscular, though there is no greatly enlarged sphincter, and the margin is frequently produced into broad, highly contractile lobes correlated with the shell-sculpture[3] ; there is also a broad lobe corresponding to the thickened columellar callus ;

(*c*) the marginal teeth of the radula are relatively narrow ;

(*d*) the inner wall of the stomach is thrown into transverse folds, which are frequently chitinized ;

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[1] Hanley and Theobald, *Conchologia Indica*, p. 45, pl. cx, fig. 4 (1876).

[2] Kobelt perpetuates the erroneous belief that this is an African species in his monograph on "Paludina" in the *Couch. Cab.* (1909), p. 172. Cf. Hanley and Theobald, *Conch. Ind.*, p. 33 (1876).

[3] Annandale, *Proc. Roy. Soc.*, XCVI, p. 67, fig. 5 (1924).

(*e*) the central nervous system is relatively very large, with broad ganglia and greatly thickened commissures ;

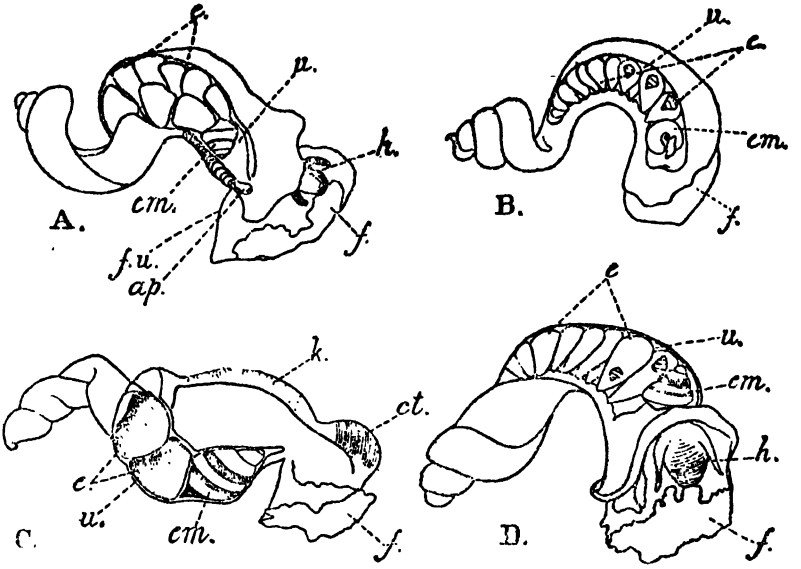


Fig. 7.—Uterus of species of *Taia* cut open to show the form and disposition of embryos and ova.

A. *T. crassicallosa.*
B *T. shanensis.*
C. *T. intha.*
D. *T. naticoides* f. *intermedia.*

ap. anal papilla ; *ct.* ctenidium ; *e.* ova ; *cm.* embryo ; *f.* foot ; *fu.* folds of uterus *h.* head ; *k.* kidney ; *u* uterus. The dotted line from *fu.* should reach the folds shown behind the anal papilla *ap.*

(*f*) the uterus contains only a small number of embryos, which are more fully developed at birth than in *Vivipara* ;

(*g*) the gill-filaments are high and narrow with a short base of attachment.

The question of the relative fertility of the different species has been considered by Annandale (*Proc. Roy. Soc.* XCVI, p. 70, 1924) in reference to their evolution. An interesting point in this connexion is the proportionate numbers of the sexes, for we have to consider the number of developed embryos and not merely that of unfertilized ova. In *T. naticoides* f. *intermedia* only four males were found among 25 individuals : in *T. crassicallosa* there were 4 males to 6 females ; in *T. intha* 22 males to 27 females ; in *T. shanensis* 18 males to 14 females ; in *T. elitoralis* 10 males to 4 females. The numbers of individuals are small, but it would appear that while in the two species which live in streams or in paludine conditions the number of females predominates over that of males, while the opposite is the condition in lacustrine and even paludine forms. There is thus further evidence for the reduction in fertility of the latter.

The examination of much further material renders it necessary to combine several of the forms hitherto regarded as distinct species, but

on the other hand reveals the existence of yet another new species in the Inlé valley. We have thus the following living forms in the Inlé watershed :—

Taia naticoides race *intermedia*, Annand.
Taia theobaldi (Kobelt).
Taia crassicallosa, sp. nov.
Taia shanensis (Kobelt).
Taia elitoralis, Annand.
Taia intha, Annand.

With the exception of *T. theobaldi*, which we have not examined anatomically, these five forms are distinguished by apparently constant characters in the soft parts as well as the shells.

Four fossil or subfossil species also occur in the same area, namely : *Taia naticoides* race *lacustris*, Annand., *Taia conica*, Annand., *Taia obesa*, Annand., *Taia cylindrica*, Annand.

The first of these is known to us from the lacustrine deposit above the He-Ho gorge, while the other three were found in two small limestone caves at Hsin Dawng, a few miles from the town of Yawnghwe.

We have recently received from Mr. F. W. Walker of the Geological Survey of India a number of shells of the species described by one of us as *Taia incisa*[1] and later made the type of the subgenus or genus *Temnotaia*.[2] In some of Mr. Walker's specimens the operculum remains. It proves that the species is really a Melaniid and not a Viviparid. *Temnotaia*, therefore, if it is to be retained, is no more than a section of *Paludomus* and a new name must be found for the smooth and thick-shelled forms of *Taia*. That of *Lissotaia* is here proposed. The species are *fulva* (Reeve), *concolor* (Nevill) and *bhamoensis* (Nevill). It is perhaps best, until their anatomy is known, to regard them as representing merely a subgenus of *Taia*.

Taia naticoides (Theobald).

As Annandale pointed out in his original description of the Inlé species of the genus, the form that occurs commonly in swamps and backwaters in the Inlé valley is specifically identical with Theobald's species, but shells from the valley are not precisely identical with those from the upper Salween, whence T. *naticoides* was originally described. Further, they differ slightly *on an average* from those from the He-Ho plain on the same watershed but 800 feet higher. Living specimens from the latter locality were thought to differ from subfossil shells from the superficial peaty deposits on the same plain, and these subfossil shells were separated into two species. The difference between living Inlé and He-Ho individuals are, however, so slight that it does not seem advisable to recognize them by the use of different names, while the living He-Ho form is found to grade absolutely into the common subfossil form originally called *intermedia* of which the form *analoga* proves to be a mere monstrosity or aberration.

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[1] Annandale, *Rec. Ind. Mus.*, XIV, p. 213, fig. (1918).
[2] Annandale, *Rec. Geol. Surv. Ind.* L., p. 231 (1919) and *Rec. Ind. Mus.*, XXII, p. 293 (1921).

We think it best, therefore, to combine all the living and fossil forms of this species from the two connected valleys under the name :

Race **intermedia**.

1918. *Taia naticoides* (in part), *T. intermedia* and *T. analoga*, Annandale, *op. cit.* pp. 126, 128, 132, pl. xv, figs. 6, 7, 12, 13, 16, 17 ; pl. xvi, figs. 3—6, 7—9 ; pl. xvii, figs. 3, 4 ; pl. xviii, figs. 1—3.

The shell of this race is rather more elongate and frequently much larger than that of the *forma typica* from the Upper Salween. It is, moreover, never wholly devoid of coarse spiral ridges, though they vary greatly in development.

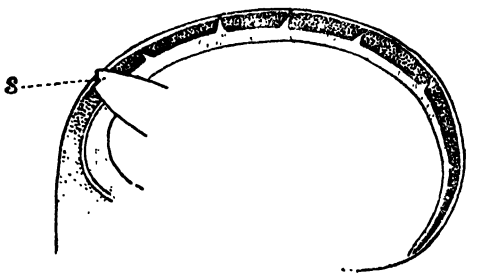


FIG. 8.—Mantle edge of young specimen of *Taia. naticoides* f. *intermedia* as seen from below. *S.* siphon.

The stomach of this form has a distinct chitinous lining and a pair of parallel chitinous ridges of a pinkish colour are usually to be found a little below the junction of the stomach and oesophagus. They are not always to be detected, however, and it is possible that they are worn out or cast off and replaced periodically.

The gill-filaments are very narrow ; their base is somewhat produced backwards.

The auricle of the heart is a lobed structure, larger than the spongy, thick-walled ventricle.

The uterus as a rule contains several embryos with well-developed shells, but two of these are usually larger and better developed than the others. About nine polygonal compressed eggs are also present ; altogether there may be as many as thirty eggs and embryos. The embryonic shells are always banded.

Of 25 individuals examined at the Inlè Lake only 4 were males.

Race **lacustris** Annandale.

1918. *Taia lacustris*, Annandale, *op. cit.*, p. 131, pl. xv, fig. 10 (*not* 11) ; pl. xvii, fig. 1 ; pl. xviii, figs. 7, 8 (*not* 9).

The shell of this fossil form only differs from that of the race *intermedia* in being a little longer, narrower and less conical. It never reaches a large size and is fairly constant in shape and sculpture. It occurs only in the clay banks of the He-Ho river above its gorge.

Taia shanensis (Kobelt.)

1918. *Taia shanensis*, Annandale, *op. cit.*, pl. xv, figs. 14, 15; pl. xvi, fig. 10; pl. xviii, figs. 4, 6.

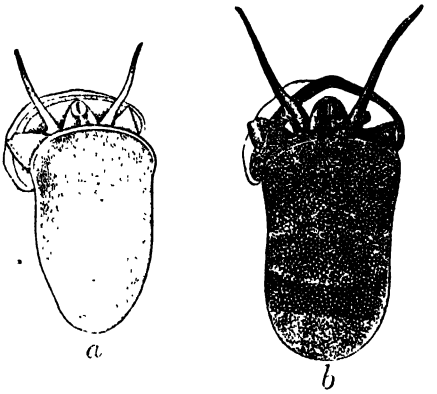


FIG. 9.—*a*. Ventral view of living animal of *Taia shanensis*, *b*. Ventral view of living animal of *Taia inlha*.

This species appears to be somewhat modified structurally in correlation with its environment, especially in three systems, namely, the shell; the respiratory system and the alimentary system, the environmental peculiarities being the very foul water in which it lives and the existence of an abundant supply of an alga containing hard calcareous particles on which it feeds. The shell is relatively thin and brittle. The chitinous lining of the stomach is particularly well-developed and the ridges and folds into which it is thrown unusually prominent, while the radular teeth are stronger than in other species. In the other direction, the gill-filaments are relatively broad, while the supraintestinal fold of the mantle running close to and parallel to the ctenidium is strongly developed and perhaps acts as an accessory organ of respiration.

The colour of the exposed parts of the living animal, including the edge of the mantle, is nearly black with the usual yellow specks.

Other anatomical peculiarities noted are that both the auricle and the ventricle of the heart are globular and that the testis is of a peculiar shape, being elongate and curved with its anterior extremity extending to the base of the right tentacle. The ejaculatory duct has a tortuous course in the tentacle.

There are usually three to five embryos with distinct shells in the uterus, one or two being further advanced than the others. About eighteen undeveloped eggs are also present as a rule. The embryonic shells are not banded.

Taia theobaldi (Kobelt.)

1918. *Taia theobaldi*, Annandale, *op. cit.*, p. 126, pl. xv, fig 18; pl. xvi, fig. 1; pl. xviii, figs. 15—17.

The spire of the shell is shorter than in any form of *T. naticoides* and the body-whorl is usually more swollen, but the most distinctive feature is in the callus, which in young shells is often ridge-like and

even when fully developed has a sharp outer edge, which often leaves a chink leading to the umbilicus open.[1]

Taia elitoralis Annandale.

1918. *Taia elitoralis*, Annandale, *op. cit.*, p. 134, pl. xv, figs. 4, 5 ; pl. xvii, figs. 5, 6 ; pl. xviii, figs. 13, 14. *Taia intha*, pl. xv, fig. 3.

Much additional material of this species, which was scantily represented in the former collection, was obtained and it becomes evident that the distinction between it and *T. intha* was not quite correctly set forth. The shells from towards the edge of the lake referred to *T. intha* really belong, as is proved by an anatomical examination, to *T. elitoralis*. This fact, while it still further limits the apparent variability of *T. intha*, which was always regarded as a peculiarly stable form, renders that of *T. elitoralis* somewhat wider. The figures cited, however, should render the matter clear.

In anatomy *T. elitoralis* stands somewhat apart from the other two species from the Inlè Lake. It differs from *T. shanensis* both in the structure of the stomach and in that of the respiratory system. The folds of the inner wall of the stomach are much less developed and there are no chitinous ridges, while the heart is better developed and the base of the gill-filaments relatively broader.

The large size of the heart may be correlated with the fact that the auricle is often filled with ova, apparently of an Echinostome trematode. No adult or larval parasites were found, probably because the time of year (March) at which the specimens were examined was unfavourable.

The number of embryos present in the uterus with shells is sometimes larger than in *T. shanensis*, but in specimens dissected at the Inlè Lake it was found that there were as a rule three such embryos, of which two were larger than the third. There are also about eight undeveloped spherical eggs, which are remarkable for their extraordinarily tough and fairly thick outer layer, which has a glistening surface. Inside this layer there is a mass of yolk with a cavity at one end in which the embryo is apparently developed. The eggs are attached to the wall of the uterus as an *Vivipara*.

Of 31 individuals examined at the lake 22 were males.

Taia intha (Annandale).

1918. *Taia intha*, Annandale, *op. cit.*, p. 135, pl xv, figs. 1, 2 ; pl. xvii, fig. 7 ; pl. xviii, figs. 10–12.

This is much the most constant species known to us as well as a species with the most highly developed shell sculpture. Its anatomy

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[1] Examination of a few specimens of this species from the N. Shan States recently sent by the Director of Public Health, Burma, has enabled me to add a short note on the anatomy. The mantle-edge has a wavy margin in some but has no definite processes. The stomach is relatively small in size and has a few raised folds on the internal wall. The gill-filaments resemble those of *T. naticoides F. intermedia* but are shorter and broader with their extremeties rounded of seven specimens examined only two were females of which one was immature. The uterus was large and contained three embryos of which the anterior was the largest, and eight much compressed eggs. The embryos were faintly banded. Several very minute spiral ridges were present on the shell, the central ones being more prominent on the last whorl [H.S.R.].

resembles that of *T. shanensis*, but the following differences have been observed. The testis has as a rule a sharp bend at its posterior end. The structure of the rectum appears to be peculiar. The inner wall is provided with transverse folds and a median ventral double ridge running longitudinally.



FIG. 10.—Front view of living animal of *Taia intha*.

The gill-filament is broad at the base but tapers to a fine and almost thread-like extremity.

The colour of the exposed parts of the living animal is pale olivaceous with yellow specks which appear to be universal in the family.

The fertility of the species is much reduced. There is often only a single very large embryo in the uterus; this occurred in six females examined consecutively at the Inlè Lake. A second, and even a third, smaller embryo is sometimes present. Undeveloped eggs are often absent and the single embryo present is often so large that it fills practically the whole cavity. It is thus not improbable that other ova are suppressed by its growth. The embryonic shell is banded.

Taia crassicallosa, sp. nov.

This species stands in much the same relation to *Taia naticoides* (Theobald) as *Taia intermedia* Annandale (here recognized as a form of *T. naticoides*), so far at any rate as the external features of the shell are concerned; but differs from both in the relatively short, broad spire, which never exceeds the height of the last whorl, and especially in the extremely broad, very prominent and greatly thickened columellar callus. The last is smooth and polished, but less so than in *T. naticoides*. The base of the aperture is slightly more oblique than that of *T. naticoides* f. *intermedia*.

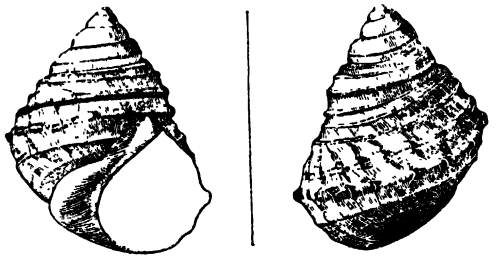


FIG. 11.—Type-specimen of *Taia crassicallosa* sp. nov. from S. Shan States.



FIG. 12.—Operculum of *Taia crassicallosa*.

Some of the smaller shells of the species seems to approach *T. obesa* Annandale in general form, but the great breadth and thickness of the columellar callus and its smooth and polished surface are sufficient to separate the species.

The degree of variability in the sculpture and ornamentation of the shell is much the same as in *T. naticoides* f. *intermedia*, but the



Fig. 13.—Embryonic shell of *Taia crassicallosa*.

tendency to form tubercular ridges on the whorls is less marked. Squamous projections are rarely formed in a regular series on the last whorl.

Measurements (in millimeters) of type-specimen.

Height of shell.	Height of aperture.	Greatest breadth of shell.	Greatest breadth of aperture.
31·5	20·0	26·0	13·0

In actual bulk this species is the largest of all living species of *Taia*.

Anatomically the species is well differentiated: it seems to be intermediate in some features between *T. naticoides* f. *intermedia* and *T. elitoralis*. The gastric cavity is, however, devoid of folds and chitinous ridges. The gill-lamella is relatively long but narrow at the base, and is intermediate in form between those of the two species mentioned. The kidney is, curiously, different in the two sexes, at any rate in the specimens examined. In the male it is triangular with an elliptical renal aperture at its posterior end, whereas in the female it is oval with the renal aperture in the middle of the ventral surface. With only a few specimens before us, however, we are unable to judge whether this difference is merely an individual variation or due to sex. The uterus is transversely folded in such a way that its external surface has the appearance of a series of lamellæ. The roof alone is involved in this folding process, while the floor has a thick, wavy longitudinal fold. There are only two full-grown embryos (without bands on the shell) and six eggs with undeveloped embryos in them.

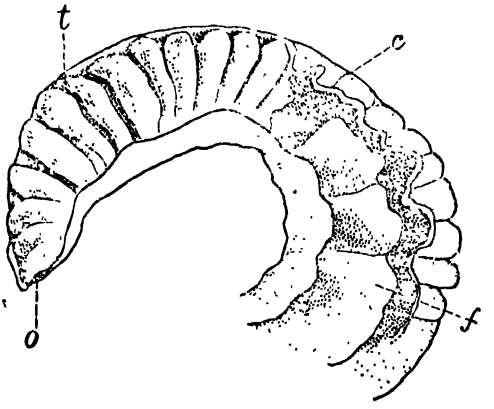


Fig. 14.—Uterus of *Taia crassicallosa* with its proximal half cut open.
o. External opening of uterus; *t* transverse folds of the dorsal wall of uterus; *c*. cavity of uterus; *f* longitudinal fold in the floor of the uterine cavity.

Anatomically the characteristic feature of this species is the peculiar structure of the uterus.

Type-specimen.—M. 12462/2 Zool. Surv. Ind. (*Ind. Mus.*).

Living and dead shells were taken by us on the edge of the Yawnghwe river near Tai-O, Yawnghwe State, S. Shan States in March, 1922. Well-preserved specimens of the species were also brought back by Dr. S. L. Hora who visited the stream in April of the same year.

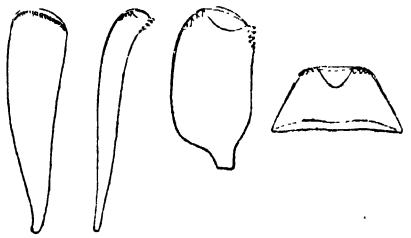


FIG. 15.—Radular teeth of *Taia crassicallosa*.

Several of the dead shells were covered by a thick calcareous deposit[1] which completely obscured their form and sculpture. Some of the bivalves obtained in the same locality had a similar deposit on them, which is due to a deposit of diatoms.

Taia obesa Annandale.

1918. *Taia obesa*. Annandale, *op. cit.*, p. 128, pl. xv, fig. 19 ; pl. xvi, fig. 2.

Two fully-grown shells larger than the type-specimen, and several young shells were obtained in the Hsin Dawng caves. Of the former, one is broken at the lip and has its spire relatively long, its total height being 46·2 mm.

The other is complete and relatively broad. It has the following measurements in millimetres :—

Height of shell.	Height of aperture	Greatest breadth of shell.	Greatest breadth of aperture
41·5	22·5	34·0	17·0

The tubercles on the spiral ridges of the shells are relatively feebly developed, especially in young individuals.

Taia cylindrica Annandale.

1918. *Taia cylindrica*, Annandale, *op. cit.*, p. 130, pl. xv, fig. 9 ; pl. xvii, fig. 2.

A large number of shells, some of them broader and higher than the type-specimen, was collected in the Hsin Dawng caves on a mud slope leading from a hole in the roof of one of the caves to the interior, but many of them are incomplete. In one of the shells we found an exceptionally large embryo, but, unfortunately, in a bad condition.

Taia conica Annandale.

1918. *Taia conica*, Annandale, *op. cit.*, p. 133, pl. xv, fig. 8 ; pl. xvii, fig. 8.

This is much the most abundant of the fossil species found in the Hsin Dawng valley. Our recent collection includes several shells smaller than any in the type-series.

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[1] We have to thank Mr. K. C. Biswas for examining the deposit. *Cf.*—Paul Ehrmann "Land-und Susswasserschnecken aus den Südl. Schan Staaten" in *Sitzungsber. Naturf.* Ges. IX, pp. 24-25, pl. i, fig. 9 : (Leipzig, 1922).

Fam. AMPULLARIDÆ.

Genus **Pila** Bolten.

1920. *Pachylabra*, Annandale, *Journ. Nat. Hist. Soc. Siam*, p. 4, pls. (i) and (ii).

Pila conica var. **compacta** (Reeve).

1918. *Ampullaria winkleyi*, Annandale, *op. cit.*, p. 138, pl. xii, fig. 10.
1921. *Pachylabra conica* var. *contracta*, *id.*, *Journ. Fed. Malay St. Mus.*, X. p. 193.
1924. *Pachylabra maura*, Annandale, *Proc. Roy. Soc.*, B, xcvi, p. 71.

We have consulted Dr. Baini Prashad, who has recently examined the type-specimens of *Pila* in various European Museums, as to our specimen. He is convinced of the identity of all from the Southern Shan States[1] and regards them as falling within the limits of the form *compacta*. As a result of Dr. Prashad's investigations considerable changes become necessary in the nomenclature of the Indian species of the genus[2].

The variety is widely distributed in Burma and occurs also in the Malay Peninsula. We obtained specimens at Loi-an near Kalaw as well as in the Inlè valley.

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[1] I take this opportunity to invite attention of an unfortunate printer's error in my paper on Malay apple-snails. A whole paragraph has been omitted after the first paragraph on page 195, *Journ. Fed. Malay St. Mus.* X, including the name *Pachylabra conica* var *compacta* in black type. The second and third paragraphs, as they stand, refer not to *P. stoliczkana*, but to this form. There are several other misprints in the paper, of which I did not see a proof but I think the others explain themselves. (*N.A.*)

[2] Prashad, *Journ. Asiat. Soc. Bengal* (N.S.), XVIII, pp 585-591 (1923).
id., *Mem. Ind. Mus.*, VIII, pp. 69-89, pl. xiii—xv (1925).

MATERIALS FOR A REVISION OF THE RECENT INDIAN LIMNAEIDAE (MOLLUSCA PULMONATA)

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INTRODUCTION.

Our object in writing this paper is to provide a means of identifying the species of *Limnaea* found in the Indian Empire. In preparing it we have had two great advantages :—We have had before us by far the largest collection of shells and spirit material of the family ever accumulated from any Oriental country, and we have been able to collect specimens and note the peculiarities of their habitat at many places scattered over a very wide area, from the Persian frontier in the west to the Southern Shan States in the east and from the Afghan frontier in the north to the Nilgiri Hills in the south. We have also been able to examine the specimens named by Nevill and other conchologists who have worked in Calcutta.

Limnaea is a very difficult genus to set in order because of the great variation exhibited by many species. This variation is of more than one type. Apart from differences due to age, we may, indeed, note three types :—(1) individual variability, (2) plasticity and (3) racial or local variation. Individual variability may be said to occur when individuals of the same species living together in the same environment differ *inter se* in colour, form or structure. This kind of variability is never completely absent, but it becomes conspicuous only when the individual differences are considerable. By plasticity we mean a physical response to environment on the part of the organism and ultimately of the race in all probability. Strictly speaking this response ought to appear in the life-time of each individual and be similar if not identical in all the individuals of any particular environment ; but we have little or no experimental evidence so far as Indian species are concerned and can only suspect that this occurs on the analogy of species observed elsewhere. Racial variation exists when all or most of the individuals of any given locality differ in small but constant characters from those of other localities. This phenomenon is not so common in *Limnaea* as it is in some genera and it is not always possible in the present state of our knowledge to distinguish it from plasticity. It may come about, however, theoretically from one of two causes, either by stabilization of plasticity owing to transmission of characters from one generation to another, in other words by a form of the

inheritance of acquired characters[1]; or by the appearance and perpetuation of mutations in isolated groups of individuals.

Our position in this matter will be rendered clearer by the citation of actual examples of the three kinds of variation. Individual variability is often well illustrated by the common *L. acuminata*. (vide *Rec. Ind. Mus.*, XXII, p. 569, fig. 12, 1921). The figure cited reproduces the outlines of a group of shells from the same locality. The species is essentially variable in certain conditions and we have no real explanation of the differences between the different shells. As an example of plasticity, *L. andersoniana* (pl. viii in the work cited above) provides excellent material. Alike in the Southern Shan States, in the valley of Manipur and probably in other localities, at least two forms of the species are found, one, with a narrow shell, living in running water, the other, with a comparatively broad shell, in still water. It is less easy to find a good case of racial variation in *Limnaea*, but we may refer to the form *siamensis* of *L. luteola*, known from widely separated parts of Burma and Siam, but not from any other country (fig. xiv, 5 & 6).

The existence of variation renders it necessary to examine large numbers of specimens from many localities. If this be done, another fact becomes evident, that plasticity and individual variability are not always correlated. In a given species we may find one and not the other, both, or neither, that is to say, present in a conspicuous degree.

As Annandale and Prashad have pointed out elsewhere[2] anatomical characters are, on the whole, even less satisfactory in differentiating the Indian species of *Limnaea* than shell-characters. The organs that have been found most useful in this respect are the genitalia, the radula and the jaws. We have examined the radula of all but two of the species known from the Indian Empire and immediately adjacent districts, and the jaws and genitalia of a large proportion. We find only three species, the Palaearctic *L. stagnalis* and *L. auricularia* and the Burmese *L. laticallosa*, in which precise diagnostic characters of a structural kind are to be found in the genitalia. In several others differences of a less definite kind such as those in the length of the various ducts occur, but on the whole the results of our examination of a large amount of material have been disappointing from a taxonomic point of view.

This has also been so with the radulae, the great majority of which, while exhibiting much individual variability and many abnormalities, are very much alike. In only a few species are exact differences to be found.

In a few species the jaws also give sound characters, but only in still fewer, and species with very different shells have sometimes very similar jaws.

We will, however, discuss the genitalia and the buccal and pharyngeal armature a little further before considering the shell.

Jaws and Radulae.

The structure of the jaws and radulae is, with a few exceptions, remarkably uniform in the Indian Limnaeidae, and in many species

[1] The phrase "inheritance of acquired characters" is commonly applied to two quite distinct phenomena or supposed phenomena :—(1) to the transmission by descent of a sudden traumatic injury or mutilation and (2) to the transmission of a modification gradually impressed upon an organism by environment from generation to generation. It is in the latter sense that we use the term.

[2] *Rec. Ind. Mus.*, XXII, p. 567 (1921).

individual variability is sufficiently great to mark any specific characters that may occur. When this is not the case specific characters may be found both in the structure of the upper jaw-piece or "mandible", as it may be conveniently called, and also in the number and shape of the radular teeth. It is rarer to find definite characters in the lateral pieces of the jaw, but in at least one species (*L. laticallosa*) they occur.

Jaw.—The jaw consists, as in species from other countries, of three pieces, the mandible and two lateral appendages. The mandible is lunate, semicircular or subquadrate in outline. Its free cutting edge may be straight, concave, convex, emarginate or sinuate. Occasionally it is produced in front into a beak-like prominence, but this appears to be an individual rather than a specific character. There is certainly no justification for regarding it as of generic significance, as was suggested by Bowell.[1] The mandible is of solid structure and composed of horny substance.

The lateral appendages, which hang down one on each side of the mouth firmly attached to the buccal muscles, are band-like or thread-like structure composed of a large number of minute transverse rods, which are as a rule firmly welded together even at the free edge which borders the mouth. In the Burmese *L. laticallosa*, however, the texture is not so firm and the edge has often a fringed or fimbriated appearance owing to the projection of individual rods.

Radula.—The structure of the radula in the Indian species is, apparently, less liable to specific variation than it is among the Limnæidae of North America[2], but agrees generally with that of most Palaearctic species of which there is any record, except that the number of teeth in a transverse row seems to be generally smaller. This is so even in Indian individuals of species common to Europe and the northern part of India, of which several exist. In Indian Limnaeidae there are rarely as many as thirty teeth on each side of the central. The number of these teeth is a good specific character, but only within wide limits and in some species. The actual size of the teeth is not always correlated with that of the animal and sometimes forms a good diagnostic character.

The teeth exhibit less structural adaptation than might perhaps have been expected. Thus, those of *L. acuminata* and those of *L. lutcola* are almost identical, in spite of a distinct difference in the habits of the two species, *L. acuminata* feeding largely on rotting vegetation, particularly on dead leaves of water-lilies, while *L. lutcola* feeds almost exclusively on organic matter from mud at the bottom.

The central, in our experience, offers few specific characters being particularly variable in shape. In all the forms we have examined the cusp consists of a relatively large, more or less triangular process bearing at its tip a minute tooth or spine. This process is never quite symmetrical but bilateral symmetry is approximately reached by some species in which the left side of the cusp is even, while the outline of the right side is sinuate or irregular. In others the irregularity on the right side takes the form of a secondary cusp. There is never any such cusp on the left side, which, however, may be very slightly irregular,

[1] In Preston, *Rec. Ind. Mus.*, III, p. 116 (1909).
[2] Baker, F.C., *Chicago Acad. Sci.* special publication No. 3 (1911)

indicating a primitive trilobed condition of the tooth. The tooth is always much smaller than any of the laterals, but its relative size is different in different species.

In all the Indian species but one (*L. hookeri*) the first lateral is normally tricuspid, its free region consisting of a large mesocone in the centre with an entocone on the side nearest the central and an ectocone on the other side. The three cusps may be subequal, but the ectocone is usually much smaller, and the entocone often considerably smaller, than the mesocone. The entocone may be reduced to a mere tubercle but this is exceptional. The teeth immediately following the first lateral usually resemble it, but in one species (the Eurasian *L. stagnalis*) they are normally bicuspid, the entocone having disappeared. In *L. hookeri* the first six laterals are bicuspid, the entocone again being absent.

The radula and jaws of some species thus provide good specific characters but among the Indian forms we find nothing in these structures that would provide a sound basis for generic or even subgeneric separation. There is, indeed, a very close general similarity, and while in some species there are quite definite and constant features in the details of the dentition, in others there is great individual variability in this respect. Species, moreover, which can be separated on well-defined shell-characters often resemble one another closely in the structure of the buccal and pharyngeal armature.

Among all the species we have examined, only seven stand out as having really characteristic structural features in the radula. They are *L. stagnalis* and *L. brevicauda* from the Kashmir valley, *L. hookeri* and *L. bowelli* from Tibet, *L. lagotis* from the Eastern and other parts of the Himalayas and *L. laticallosa* and *L. mimetica* from the Shan Plateau. All the others, whether from the Palaearctic parts of the Indian Empire, from India proper or from Burma, exhibit a close resemblance *inter se*, and specific differences, as a rule, appear not much greater than individual variablity. The only species in which we have found definite structural differences in the radula of individuals from different localities is *L. andersoniana*.

There is considerable individual variability in the number of teeth present in each transverse row and also in the proportionate numbers of laterals and marginals. In the latter character, moreover, it is often difficult to fix a limit between the two series, as the teeth of one change gradually into the type characteristic of the other. There is, nevertheless, a definite specific difference in some cases in both respects provided that latitude is allowed for variability. *L. mimetica* and *L. horae*, for example, have only about 17 laterals and marginals, while *L. stagnalis* has 28. In *L. laticallosa* there are only about 4 marginals and 23 laterals while in most species the number of marginals is much greater than that of laterals.

Abnormalities in the outline of the teeth are common. Sometimes they occur in single teeth and sometimes in whole longitudinal series. Laterals not infrequently lack the entocone even in species in which it is normally present, but though this peculiarity may occur in a whole longitudinal row, it is never, so far as we have seen, perpetuated in whole transverse series. The mesocone may be denticulated or even divided into two or more cusps, but this is not so common. The shape of the central is always somewhat variable, while the marginals exhibit

much less regularity and uniformity than do the laterals and are not infrequently monstrous in outline.

GENITALIA.

The genitalia, as in species from other countries, consist of three portions: (1) the hermaphrodite gland and its duct, (2) the male organs, including the prostate gland and the penis with their ducts and muscles, and (3) the female organs, consisting of the albumen glands, the oviduct and the spermatheca. The hermaphrodite gland and its duct lie embedded in the coils of the liver, while the male and female organs lie on the right side of the pallial cavity between the oesophagus and the rectum. The female organs are superimposed on the male and are conspicuous on opening the pallial cavity. The proximal half of the genitalia, consisting of the hermaphrodite gland, the albumen glands and the oviduct, is uniform in all the species, whereas the distal half, consisting of the uterus, the spermatheca, the prostate gland, and the penis, is subject to some variation.

The spermatheca is usually an oblong, oval or spherical sac with orange-coloured contents. Its duct commences abruptly as a narrow tube from the lower extremity of the sac and opens into the uterus close to the external opening of the latter. In *L. laticallosa*, however, the commencement of the duct has a characteristic dilatation, absent in other Indian species. The duct usually lies ventrad of the uterus and is nearly as long as the latter except in a few forms.

The prostate gland is a subcylindrical, ovoid, heart-shaped or pyriform body lying just below and a little in front of the large accessory albumen gland. The vas deferens starts from near the distal extremity of the prostate and usually has its commencement dilated. In some Indian species the prostate is bulbous, and in rare instances bilobed. Its size and shape vary in individuals of the same species, apparently according to development. Much stress has been laid on this variation in the grouping of the American species of *Limnaea* but so far as we can see without justification. So far as the Indian species at any rate are concerned no such grouping is possible. In *L. stagnalis*, *L. brevicauda*, and *L. persica*, which are confined to the north-western part of India, the prostate is a more or less bilobed structure. This character is, however, most marked in the first species, which is widely distributed in the Holarctic zone. In *L. auricularia* the outline of the gland is more ovate than in other species.

The penis is placed in front of the female opening close to the buccal mass on its right side. The vas deferens on leaving the prostate passes through the integument of the head until it reaches the male external opening where it pierces the integument and runs close to the penis. The penis-sac may be divided into a proximal narrow tubular portion, and a distal large cylindrical muscular one. The former, except in *L. stagnalis* is nearly always as long as or slightly shorter than the latter. It encloses a narrow flagellum-like structure, thin and pointed at its free end, which may conveniently be termed the true penis. The term "epiphallus" has been applied to this structure by some authors, who regard both the proximal and distal portions as the penis proper. In *L. stagnalis* the penis is much shorter than the distal portion and has its free extremity dilated into a glans-like swelling. As in the case of

the prostate gland, great importance has been attached to the variations occurring in the American species in the relative lengths of the penis and the distal portion of the sac. The Indian species, however, do not show constant variations in this respect, except between *L. stagnalis* and other species.

The penis and the penis-sac are supplied with retractor and protractor muscles. In all the species discussed here there is a single narrow retractor muscle connected with the commencement of the proximal portion. This is the retractor of the penis. A stout muscle, frequently divided into two or three bundles, is attached to the beginning of the distal muscular portion and is the retractor of the sac. There are usually four protractor muscles attached to the sides of the distal portion of the sac. They are also divided into bundles, a branch of which may connect them with the retractor of the sac. There is, however, considerable individual variability in the number and arrangement of these muscles.

In view of all these facts we do not find ourselves able to make much use of the genitalia in separating the different Indian species even into groups, much less specifically. *L. stagnalis* stands apart from the others in respect of these organs and minor differences can be noted between a few other species, but in most any specific differences that may exist at one period or another are completely masked not only by individual variability but also by differences in structure due to the sexual condition of the individual examined.

Attention has been drawn to the fact that certain species on the north-west frontier of India are functionally protandrous and pair when the male organs are fully developed,[1] storing up the spermatozoa for a period until the female organs become ripe. In the course of our investigation of numerous collections from all parts of the Indian Empire we have found much indirect evidence that this condition prevails in most, if not in all, species. It is rare, for example, to find both the prostate and the spermatheca fully developed in the same individual. Further, we have observed that egg-masses are usually scarce in bodies of water in which the snails are copulating in large numbers, and that, conversely, when egg-masses are abundant pairing does not seem to be at all common. These facts have an important bearing on the taxonomy of the genus, for many of the so-called specific and even generic characters of the genitalia are undoubtedly due to this cause.

The Shell.

Although there is in the genus *Limnaea* a certain common facies of the shell hard to define in words, there is also great diversity of outline. The common facies is perhaps best defined mainly by negatives. The shell is never thick and rarely quite opaque; external sculpture of a pronounced kind is rare and never consists of tubercles or spines. The colouration is never conspicuous and rarely diversified; if stripes are present they are never, at any rate in normal shells, spiral and are as a rule produced by differences in translucency rather than colour. Normal shells are always dextral; sinistral abnormalities have been observed, but not among Indian species. The spire varies greatly in proportionate length but is always more or less tapering and always in,

[1] Annandale and Prashad, *Rec. Ind. Mus.* XVIII, p. 22 (1919).

or practically, in the same straight line as the main axis of the shell. The body-whorl may be narrow or almost spherical, but the columella is never transverse to the main axis.

Among the Indian species almost every form of shell found in the genus occurs. *L. acuminata* f. *gracilior*, for example, approaches the extreme of elongation, while *L. brevicauda* is not far from that of rotundity.

The question that naturally arises first in considering the form of the shell, in view of the great variation often displayed within the limits of a single species, is : How far is form of shell correlated with environment? To this question we are not in a position to give a definite answer. Smallness of spire and inflation of the body-whorl are often correlated with a true lacustrine habitat, but the only definite Indian example we can cite is *L. brevicauda* from the lakes of Kashmir. The very narrow, and also very small and fragile *L. mimetica* from the Inlé Lake in the Southern Shan States is perhaps a still more typically lacustrine form. It resembles the deep-water *Limnææ* of the Swiss lakes, but occurs in shallow water, and no deep-water form has been obtained in any oriental lake. In *L. acuminata* narrow and comparatively broad individuals, apparently of identical habits, occur in the same pond. The only character that the shells of *L. mimetica* and *L. brevicauda* have in common is the reduction of the spire. This feature they share, perhaps by a mere coincidence, with a single individual of *L. acuminata* from the Loktak Lake in Manipur in which individuals from open water have a slightly more inflated body-whorl than those from the edge of the lake.[1]

Where food is scanty, as in pools devoid of aquatic vegetation, the animal, and therefore the shell which covers it, is always small, and the few forms that can live in running water have rather or even very thin shells. Most shells from high altitudes are small, but those of *L. stagnalis* from Kashmir, where they occur at 6,000 feet, are the largest of any Indian *Limnaea*.

Beyond this we cannot go much further. There does seem to be a precise correlation between environment and shell-characters in certain species, for example in *L. andersoniana*, in which we can recognize at least three phases, a broad phase (the *forma typica*) in still water with much vegetation, a narrower phase in running water without vegetation and a still narrower phase in rapid-running hill-torrents. Indeed, there is even a phase intermediate between the first two living in ponds into which streams run at certain times of the year. But against this we must set off the facts, already mentioned, that the completely lacustrine *L. mimetica*, from a district in which at least the first two phases of *L. andersoniana* are common, is narrow, and that all forms, from the extremely narrow to almost the broadest, of *L. acuminata* can sometimes be found in the same pond. It is not possible at present to formulate any rule, and until it has been feasible to make a complete chemical and physical examination of the environment in which every species and every form of each species normally occurs, our views on shell-variation must be largely speculative. Two things only are clear, that the shell is much more variable in some species than in others and that in some species the variation can be associated with differences in environment, while in others it cannot.

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[1] *Rec. Ind. Mus.*, XXII, p. 570 (1921).

The shell-characters of the living Indian species afford no grounds for recognizing more than one genus among them. Among the fossil forms, those to which the name *Acella* Haldeman has been applied seem at first sight very distinct, with their extremely narrow, elongate shell ; but the shell of *L. acuminata* f. *gracilior* provides a transition from the normal type, and among the species described from the Intertrappean beds of the Central Provinces intermediate forms occur, for example, *L. subulata*.

Among the living Indian species practically the full range of size that exists in the genus is to be found, from *L. stagnalis*, the shell of which may be over 30 mm. long, to *L. mimetica*, in which it does not exceed 7 mm.

Classification of the Indian Limnaeidæ

The living Indian Limnæidæ can be separated on both conchological and anatomical characters into four groups all of which have been described from other parts of the world and regarded by different authorities as having subgeneric or even generic rank. The type-species of all but one are included in the Indian fauna. The characters on which the groups are based, however, are so small and so liable to both individual and specific variation that we do not consider it justifiable to regard the groups even as subgenera. It seems simpler to accept the divisions merely as groups in a single genus *Limnaea* and use the "sub-generic" names that have been applied to them merely as a convenient method of recognizing their relationships. These four groups may be defined as follows :—

I. *Limnaea* s.s.

Shell large, with the spire long, slender and tapering and the body-whorl more or less inflated. *Radula* with most of the laterals bicuspid. *Male intromittent organ* with the proximal part (epiphallus) stout and much shorter than the distal part (penis) ; prostate bulbous or bilobed.

Type-species—*L. stagnalis* (Linn).

II. *Radix* Montfort.

Shell of variable size, rarely very small, with the spire acuminate, never very long and often very short and the body-whorl inflated and usually expanded, with the outer lip more or less broadly flattened. *Radula* with the laterals tricuspid. *Male intromittent organ* with the proximal part slender and at least nearly as long as the distal part ; prostate subcylindrical or pyriform.

Type-species—*L. auricularia* (Linn).

III. *Galba* Schrank.

Shell never large, comparatively narrow with the spire long or moderate ; the body-whorl never expanded or inflated and the lip not flattened ; the columellar fold always exceptionally broad and coarse : *Radula* with the laterals tricuspid, the mesocone being exceptionally long as compared with the base of the tooth, the entocone sometimes reduced. Genitalia as in *Radix*.

Type-species—*L. truncatula* (Müll).

IV. *Pseudosuccinea* Baker.

Shell of variable size, never very large, with its spire extremely variable in length but never scalariform though always gyrate; body-whorl never greatly expanded. Columellar fold forming a fine lamella, as a rule in close contact with the shell. Radula with laterals tricuspid, and the mesocone comparatively short; genitalia as in *Radix*.

Type-species---*L. columella* Say (American).

If we include the fossil species found in India we must recognize another division, perhaps more distinct than any of the four discussed, perhaps worthy indeed of true subgeneric rank. This is *Acella* Haldeman, originally instituted for a living American species but also including, to judge of course by shell characters alone, a number of forms from the Eocene of Europe and several from the Intertrappean beds (late Cretaceous) of the Central Provinces of India. In *Acella* the shell is extremely narrow and the suture very oblique, so that the whole shell assumes a constricted subcylindrical form, with the body-whorl much contracted.

Before discussing the species *seriatim* we may say a word about our descriptions. Mere concise technical diagnoses of the shell seem to us of little value in a genus like *Limnaea*, in which only the salient specific characters call for notice. Too great attention to consistency, indeed, tends to obscure rather than elucidate, and we have striven both in our keys and in our descriptions to describe the characters that appeal to us as distinctive rather than to insist on a mathematical precision in the definition of outlines and shapes that are not only variable but also involve the recognition of complex and elusive curves. In one species specific distinction may depend on the structure of the columella, in another on the form of the spire and in yet another on radular characters. It is very rare to find sound diagnostic characters in so many different features, much commoner to be able to select only some one small structural point as the ultimate difference, apart from a peculiarity of facies better shown in a good figure than in any description. In short, it is often more scientific to rely on good figures than on descriptions in words.

We must express our great indebtedness to the artists of the Zoological Survey of India, who have so ably reproduced the salient features of the shells under our supervison.

Family **Limnaeidae.**

The family consists of aquatic Pulmonata of the suborder Basommatophora. It is distinguished from the other families of the suborder by the following combination of characters. The shell is thin, normally dextral, spiral, more or less ovate, always less than 50 mm. and almost always more than 5 mm. long. The tentacles are flattened and triangular and the eyes, which are completely sessile, are situated externally at their base. The pulmonary chamber is ample and there is no accessory breathing apparatus or pseudobranch. The blood is colourless. The jaw consists of a stout mandible with an accessory ribbon-shaped appendage hanging down on each side of the mouth. The central tooth of the radula is small and, though often obscurely trilobed, unicuspid. The lateral teeth are tricuspid or bicuspid and the marginals pectinate,

without a lateral process. The region of the stomach is divisible into three portions. The anterior oval crop, the middle stomach proper enclosed by the highly muscular bilobed gizzard and the posterior tapering pylorus from which commences the intestine. There are no pyloric appendages. The kidney is broad and forms the roof of a greater portion of the pulmonary chamber. The male intromittent organ is long and devoid of a flagellum.

Genus **Limnaea** Lamarck.

1911. Subfamily Lymnaeinae, Baker, *Chicago Acid. Sci.* sp. publ. III, p. 125.

We do not propose to enter into the controversy as to the correct spelling of the name of the genus, whether *Lymnaeus*, *Lymnaea*, *Limnaeus*, *Limnaea* or any other variant. We merely adopt the best-known form. A full synonomy is given by Baker (*op. cit.*) in his exhaustive account of the North American species. Although we differ from this author not only as to the spelling of the name but also as to the value to be attached to anatomical and other characters, we must express our great indebtedness to his important monograph.

The great majority of the members of the family Limnaeidae fall, in our opinion, into this one genus. The only species, indeed, that we have had an opportunity of examining which we are prepared to separate generically is the Japanese *Omia japonica* (Preston)[1]. It differs from *Limnaea* in its neritiform shell, with its almost transverse columella and oblique spire, but has a similar radula and jaw. Unfortunately the anatomy is unknown.

Limnaea (s.s.).

1911. *Lymnaea*, Baker, *Chicago Acid. Sci*, sp. publ. III, p. 134.

Baker gives an excellent synonomy, which we need not duplicate. No student of the Limnaeidae can afford to be without his book.

Only one Indian species can be assigned to this group. It is *L. stagnalis*, the type-species of the genus, a Palaearctic form found in the upper waters of the Indus and in Chitral.

Limnaea stagnalis (Linn.).

1758. *Helix stagnalis*, Linnaeus, *Syst. Nat.* (Ed. X), I, p. 774.
1835. *Limnaeus stagnalis*, Rossmässler, *Icon. Land und Süssw. Moll.* I, p. 95, pl. ii, fig. 49.
1867. *Limnaeus stagnalis*, Shrenck, *Kais. Akad. Wiss. St Petersbourg*, II, p. 643.
1871. *Limnaea stagnalis*, Kobelt, *Malakozool. Blatt.* XVIII, pp. 108—119. pls. ii, iii.
1877. *Limnaea stagnalis*, Kobelt, *Rossmässler's Icon.* V, pp 35–37, figs., 1230—1233.
1884. *Limnaea stagnalis*, Kobelt, *id.* (*n.f.*), I, pp. 57, 58, figs. 168—176.
1911. *Lymnaea stagnalis*, Baker, *Chicago Acad. Sci.* (Sp. Publ.), pp. 136—140, pl. xix, figs. 1—3. 4—10; pl. xx, figs. 1—6; pl. xxii, figs. 1—3.
1915. *Limnaea stagnalis*, Preston, *Faun. Brit. Ind. Freshw. Moll.*, p. 106.

The literature on this common European and American species is very extensive and we have given only a few of the more important

[1] See Annandale & Prashad, *Journ. Asiat. Soc. Bengal* (n.s.), XIV, pp. 460-461 fig. 2, pl. xii, figs. 4, 4a, 5 (1918).

references ; a detailed list of its synonomy will be found in Baker's monograph cited above. There has never been any dispute as to the identity of this species, but it has been the cause of a great deal of discussion owing to the very different interpretations which various authors have placed on the limitation of its varieties and forms. Bourguignat [1] described all the different forms and phases as distinct species, and was to some extent followed by Collins [2] in Belgium as well as by other French malacologists. Kobelt, who undoubtedly has very extensive materials for his studies of the species, tried to reduce to order the confused state of affairs, but did not publish any really critical and exhaustive memoir with a full synonomy. We will content ourselves here with notes on the Indian forms of the species.

We are greatly indebted to Dr. B. Prashad, who has had the opportunity of comparing Indian material with the specimens in a number of European museums, for the following notes:

"Of the earlier authors Cuvier and Valenciennes [3] recorded the occurrence of *Limnaea stagnalis* in Kashmir from collections made in that area by Jacquemont. Woodward [4] also recorded a find of the species from the same area without any further details. Von Martens refers to the occurrence of one or other of the forms of *L. stagnalis* in various parts of Central Asia, and in two of his papers [5] has given useful tables showing the distribution of *L. stagnalis* and other land and freshwater molluscs in these countries. Theobald [6] also includes *L. stagnalis* in his list of the Kashmir mollusca, and is followed by Godwin-Austen [7].

"Besides the older collections in the Indian Museum there are large numbers of fresh shells collected by the Zoological Survey party in various parts of Kashmir during the summer of 1921. Various other smaller collections made in the same area and sent to the Indian Museum from time to time are also before me. In this large series of shells I am able to distinguish two distinct forms :—(1) a race described under the new name *kashmiriensis* and (2) a depauperated form of this new race for which I have selected the name *minor* Kobelt, as I am unable to distinguish it by any characters from the European form described under this name.

Race **kashmiriensis,** Prashad nov.

" This race which I have, after great hesitation, described as new, is closely allied to Kobelt's var. *palustriformis* [8] from the Euphrates. The variety was found by the Zoological Survey party to be widely distributed in the lakes of Kashmir, for example in the Dal Lake, Wular Lake, Anchar Lake and other smaller lakes ; shells were also found in

[1] Bourguignat, *Les Spicileges Malacologiques*, pp. 93—103 (Paris, 1862).
[2] Collins, *Ann. Soc. Malacol. Belgique* VII, pp. 81—94, pl. iv (1872).
[3] Cuvier et Valenciennes, *Hist. Nat. des Poissons* XV, p. x (1840).
[4] Woodward, *Proc. Zool. Soc. London*, pp. 186, 187 (1856) and *Ann. Mag. Nat. Hist* (2) XIX, pp. 409, 410 (1857).
[5] Von Martens, *Mem. L'Acad. Imp. Sci St. Petersbourg* (VIII), XXX, pp. 1 –66 5 pls. 1882), Mollusca of Russian Turkestan in *Wiss. Anhang zu Russisch-Central-Asien* von Henry Lansdell, pp. 41—47 (Leipzig ; 1885).
[6] Theobald, *Journ. As. Soc. Bengal*, XLVII, pt. 2, pp. 141—149 (1878).
[7] Godwin-Austen, *Proc. Mal. Soc. London*, III, pp 261, 262 (1899).
[8] Kobelt, *Malakozool, Blatt.* XVIII, p. 112, pl. iii. fig. 12 (1871), and *Rossmässler's Icon.* V, p. 35, fig. 1237 (1877).

the streams flowing out of the lakes, but these are not true inhabitants of the streams, being only carried into them with the current. I may also include here a note as to the lake areas. They are fairly large expanses of water sometimes extending over a couple of miles or more ; with the water in most of them not very deep, usually 5–6 feet somewhat clear but in most cases muddy and foul ; very rich in aquatic plants and the bottom consisting of decayed vegetable debris. Except where the stream is flowing out there is no current in these lakes. The Limnaeas were all found along or near the banks and the form here described is, from its characters, to be classified as one of Kobelt's " Sumpformen ". These forms have a thin, fragile shell, with a wide mouth and the body-whorl in practically all of them is shouldered or ridged.

" The shell is very large, rather thin and fragile for the size of the species ; of a brownish horny colour and in most of the specimens coated with an algal growth. The surface of the shell is regularly decussated, and has a regular sculpture consisting of fine ridges ; on the penultimate and the body-whorl these longitudinal ridges become rather prominent. The apex is acuminate and somewhat acute ; the spire prominent and occupying $\frac{2}{5}$ of the total length in the dorsal view. The suture is deeply impressed and distinctly oblique. There are 6—$6\frac{1}{2}$ whorls ; of these the first four are not greatly swollen and increase regularly in size ; the penultimate whorl, however, suddenly grows larger and is moderately swollen. The body-whorl is large, and in dorsal view somewhat ovoidal in outline ; its inner outline is somewhat sinuate below near the anterior angle, but owing to the stumpy appearance of the shell the curving is not quite regular. The outline of the outer lip differs in examples from various areas : it is either regularly curved with only a trace of the shoulder near the posterior margin, or owing to the presence of a distinct shoulder it becomes distinctly angulate. The mouth is large, but not greatly expanded, over one and a half times as long as broad, somewhat elongate, either ovoidal in shape, or in shells with a marked shoulder it has a straight anterior base and becomes quadrangular. The outer lip is sharp, neither expanded nor retroverted. The peristome is continuous ; the callus broad and thick extending over the umbilicus, but free along a short distance anteriorly ; the columella shows a distinct and deep fold.

" *Type-series.*—No. M. $\frac{12506}{2}$ in the Zoological Survey of India, Indian Museum, from the Wular Lake, Kashmir."

Anatomy.—In general anatomy the Indian variety described above agrees with that of the European material with which we have compared it, and also with the published descriptions and figures (see Stiebel [1], and Baker *loc. cit.*)

Indian and European specimens differ from all the American forms described by Baker in having the first lateral tooth of the radula constantly tricuspid.[2] Several teeth in each longitudinal row in the

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[1] Stiebel, *Limnei stagnalis Anatomie*, pp. 1–52, pls i, ii ; Gottingen (1815).

[2] Cooke's figure in the *Cambridge Natural History* (Vol. III, p. 235) shows the central as large as the laterals, but the tooth figured is probably the first lateral. It differs, however, from our preparations of both European and Indian radulae in having the entocone as large as, instead of considerably smaller than, the entocone.

same series, including the second tooth, are, however, always tricuspid. In this respect the species differs from all others described from the Indian Empire except *L. hookeri*, in which the entocone or cusp nearest the centre of the radula is much reduced in the first lateral. In Indian specimens the radular formula is approximately 13. 15. 1. 15. 13.

The genitalia agree with published figures of both European and American forms, allowance being made for the fact that our materia lis preserved in strong alcohol, but individuals of the same batch differ considerably in the shape of the prostate. Our figure represents the genitalia of one in which the gland is very fully developed. The form of the male intromittent organ is different in the glans-like structure of the morphological apex from that of any other Indian species we have examined.

" *Relationships.*—In certain respects this race comes near *palustriformis*, Kobelt (*op. cit.*), but differs in the shell being much larger with a less compact shell-substance, the mouth less expanded, spire much longer and the suture more impressed; while in most of the shells the prominent shouldering of the body-whorl is an outstanding character. I have no doubt as to this race being different from the one referred to as *expansilabris* Hartmann by von Martens (*loc. cit.*, p. 32, pl. iv, fig. 2) from the valley of the Tarim. He also recorded this form later (*Sitzungsber. Ges. Naturfor. Freunde*, Berlin, p. 240, 1887) and Weber[1] has recently recorded the same form from '*Dscharkentischen Kreis*' in Central Asia."

Geographical distribution of the species.—*L. stagnalis* (*s. l.*) is found all over southern and central Europe and in many northern localities. In the British Isles the range does not extend north of the Lowlands of Scotland, into which some naturalists think it has been introduced artificially. It is, however, common in the small lochs round Edinburgh. The species also occurs in North Africa and in Northern and Central Asia, whence it has made its way down the upper waters of the Indus system into the Kashmir valley, in the lakes of which it is common. It has not been found elsewhere in the Indian Empire[2] except at high altitudes in Chitral. Local races have been described from North America.

Form **minor**, Kobelt.

1871. *Limnaea stagnalis* var. *minor*, Kobelt, *Malakozool. Blatt.* XVIII, p. 115, pl ii, fig. 5.
1877. *Limnaea stagnalis* var. *minor*, Kobelt, *Rossmässler's Icon.* V, p. 35, fig. 1233.
1882. *Limnaea stagnalis* var. *minor*, von Martens, *Mem. Acad Imp. St. Petersbourg*, XXX, p. 33, pl. iv, fig. 1.

" Kobelt's description and figures of the form as also those given by von Martens are enough to recognize this form. I have also examined shells out of Kobelt's and von Martens' series. It is a depauperated or

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[1] Weber, *Abh. Konig. Bayer. Akad. Wiss.* (*Math. Phys. Klasse*) XXVI, p 20 (1913).

[2] Schlesch's record of the occurrence of *L. stagnalis* near Hoti Mardan published in the *Rec. Ind Mus*, II, p 108 (1908) needs confirmation In spite of careful collecting in that are.. we have failed to find any specimens of this mollusc

dwarfed form belonging to the category of Kobelt's "Hungerformen." In characterizing the surroundings in which such forms occur Kobelt states that the localities are not suited for the animals, usually have a poor food supply and are mostly temporary areas of water with a very low temperature. Kobelt's type-series was obtained from near Lyon, France, and he also had specimens from artificial ponds in the Rhone Valley. Von Marten's specimens were collected near Kashgar.

"The Kashmir specimens, which I assign to this form, are not genetically related to the type-series, but have apparently under similar biological conditions converged to the European and Central Asiatic forms. The Kashmir specimens are a dwarfed form of what has been described above as the race *kashmiriensis*, nov. but the race-characters as in the case of *Vivipara bengalensis*[1] have become modified or disguised by the peculiar surroundings in which the animals were living.

"The Kashmir shells are usually of a brownish-horny colour, but some of the specimens owing to a black incrustation on the surface, appear quite dark. The shell-substance is fairly compact, but not very thick. There are usually 5 whorls, but the apex in most cases is eroded. The spire is elongate, stumpy with whorls somewhat swollen, the penultimate whorl being markedly so. The body-whorl, which is not very large, is elongate-rounded, somewhat pear-shaped in dorsal view and without any shoulder or keel. The mouth is ovoidal, but in some specimens this is not so marked owing to the straight outer lip. The columellar callus is distinctly, but deeply arched; its upper margin is straight and it is free in its posterior $\frac{1}{3}$ from the shell. The shell is vertically striate, the striae becoming more marked and like ribs on the body-whorls.

Locality.—Specimens were found in a fair-sized 2-3 feet deep pool of water at Srinagar, Kashmir (alt. 5,200 ft.). The pool was a temporary area of water full of aquatic weeds like *Potamogeton*, *Hydrilla*, *Nymphaea* and *Spyrogyra*. The Limnaeas were very abundant in this pool and hundreds of dead shells were lying along the banks."

Other specimens of this form were obtained by Mr. G. H. Tipper, Geological Survey of India, in Shandur Lake, Shandur Pass between Chitral and Gilgit at an elevation of 12,300 feet.

Radix Montfort.

1911. *Radix*, Baker, *op. cit*, p. 178.
1915. *Gulnaria*, Preston, *Faun. Brit. Ind. Freshw. Moll.*, p. 110.

This is another Palaearctic group so far as India is concerned. The four species that occur in the Indian Empire are the type-species (*L. auricularia*) and *L. lagotis*, another European species, with *L. persica* and *L. brevicauda*, which are allied respectively to *L. auricularia* and *L. lagotis*. *L. persica* as its name implies, was originally described from Persia, but also occurs in North-Western India and (exceptionally) in the Deccan. The other three species are found in the Western Himalayas.

[1] Annandale, *Rec. Ind. Mus*, XXII, p. 270 (1921)

Limnaea persica Issel.

1919. *Limnaea persica*, Annandale & Prashad, *Rec. Ind. Mus.*, XVIII, p. 41, pl V, figs. 3–6.

This species has recently been described in detail, so far as the shell is concerned, in the paper cited. We have extracted the radula and examined the anatomy of specimens from Kumaon. The radular teeth are remarkable so far as the laterals and inner marginals are concerned, for their great breadth. The first 14 teeth are tricuspid while the other laterals, when not abnormal, as is often the case, have a series of 4 to 6 relatively broad but sharply pointed transverse cusps with two small lateral projections on the outer margin. The marginals are narrow and elongate with only 2 or 3 cusps. The formula is approximately 24. 11. 1. 11. 24, but the differences between laterals and marginals appear so gradually that it is difficult to make a distinction, and it would perhaps be more correct to give the formula as 35. 1. 35.

The genitalia do not differ greatly from those of other Indian species except that the penis is slender and not quite equal in length to the distal part of the penis-sac. It has, however, no terminal swelling. The prostate in the specimen examined is kidney-shaped. The spermatheca has a fine duct equal in length to that of the uterus.

Geographical distribution.—The species was originally described from Kerman in southern Persia. It has also been found in the Baluch desert near Nushki, on the North-West Frontier of India near Peshawar, in the Punjab Salt Range, in the Kumaon Lakes and in the Kangra valley in the Himalayas. We have examined several specimens from a large reservoir at Secunderabad near Hyderabad, Deccan. *L. persica.* therefore, appears to be the only Palaearctic species of the genus that penetrates into Peninsular India.

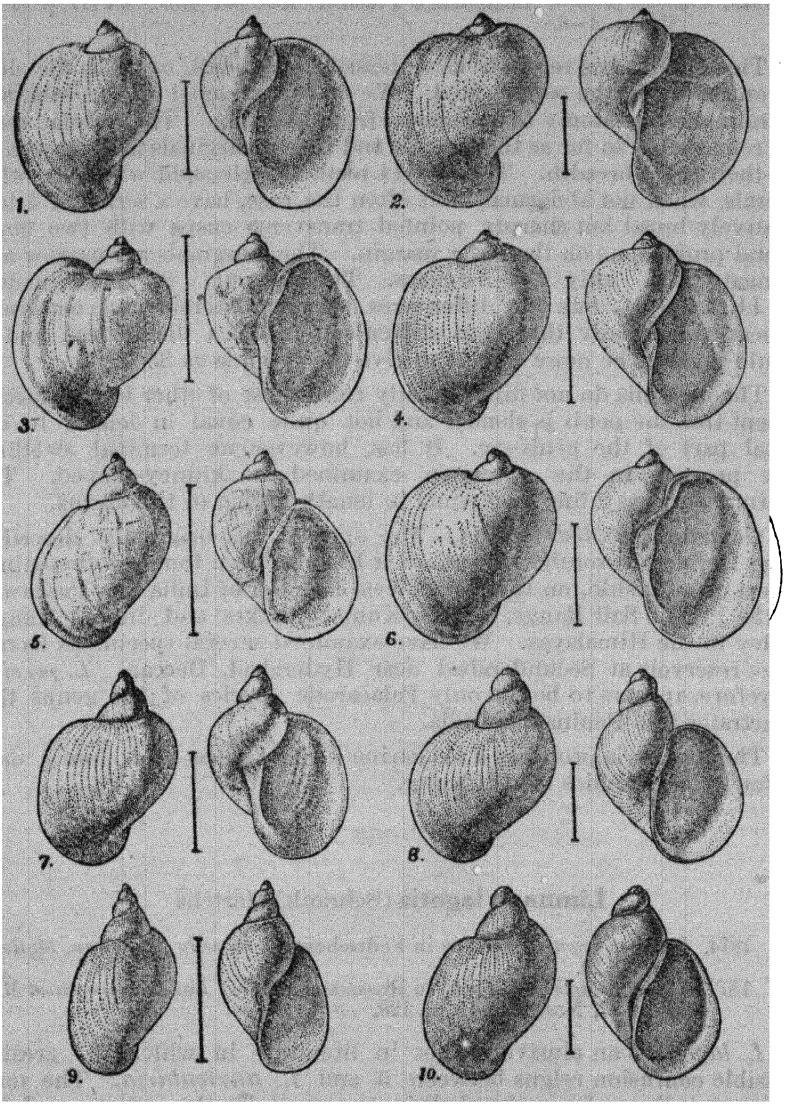
The species is probably a lacustrine form. It has been found only in fairly large bodies of still water.

Limnaea lagotis (Schrank) Martens

1874. *Limnaea lagotis*, Martens in Fedtschenko's *Reise in Turkestan, Mollusca* pl. ii, fig. 22.
1877. *Limnaea lagotis*, Kobelt in Rossmässler, *Icon. Land u. Süsswass Moll.* V. p. 37, Nos. 1240-41, pl. 128.

L. lagotis is an elusive species in literature in which the greatest possible confusion reigns between it and *L. auricularia*. The main differences lie, so far as the shell is concerned, in the structure of the spire and of the columellar fold. In *L. auricularia* the suture is impressed and the whorls are fairly convex, but in *L. lagotis* these features are greatly exaggerated, so that the spire assumes a scalariform structure, as though it were disintegrating and about to unwind. In forms of this species in which the spire is very short it has the appearance of being deeply sunk into the body-whorl and is surrounded by a regular furrow or canal at its base. The differences in the form of the columellar fold are discussed under *L. auricularia*. Otherwise the shells of *L. auricularia* and *L. lagotis* are very much alike. Both are characterized by the fact that at any rate in the adult the outer lip is

greatly expanded and forms a wide uniform arc, as a rule practically a semi-circle, with the transverse axis at right angles to the main axis of



1. *Limnaea lagotis* f. *striata*
2. *L. auricularia.*
3. *L. lagotis* f. *solidissima.*
4. *L. auricularia.*
5. *L. lagotis* f. *solidissima.*
6. *L. brevicauda.*
7. *L. lagotis* f. *costulata.*
8. *L. lagotis* f. *subdisjuncta.*
9. *L. lagotis* f. *defilippii.*
10. *L. lagotis* f. *subdisjuncta.*

the shell. The margin of the lip is rather broadly flattened. Apparently *L. lagotis* never attains the same dimensions as those of large specimens of *L. auricularia.*

We have no information as to the radula or genitalia of the typical form, which has not been found in India. No less than five forms occur in the Western Himalayas.

Form **striata** Andreae.

1913 *Limnaea lagotis* var. *striata*, Weber. *Abh. K. Bayer. Akad. Wiss (Math. Phys. Kl.)* XXVI, pt. V, p. 24, pl. i, figs. 10 *a-h* (except *e* and *g*).

This form, judged from the figures published by Kobelt and Martens, differs from the European *forma typica* in its more expanded mouth, which extends further up the shell. In specimens from Kashmir the shell is thin, and of a pale horny colour with fine longitudinal striae. There is considerable variation in the shape of the mouth, which is sometimes auriculate and sometimes semi-circular. The columellar fold is broad and well-developed. The largest specimen we have seen from Kashmir has the shell 23 mm. long and 17·5 mm. broad the mouth being 19 mm. long and 11·5 mm. broad. Most shells are considerably smaller.

The radula has comparatively large teeth but the central is relatively small. The tooth has the main cusp remarkably long and narrow and separated by a very distinct notch from a lateral cusp on the right side. The laterals are tricuspid with all the cusps well-developed, the entocone and ectocone being subequal with the mesocone larger. Those near the centre of the band are broad in proportion to their length but gradually become narrower from within outwards. The inner marginals have five or more large transverse cusps the outermost of which is very large and broad, and also two well-developed lateral teeth on the outer margin. The formula is approximately 29. 10. 1. 10. 29.

The genitalia resemble those of *L. brevicauda*, but the duct of the spermatheca is relatively wide.

Geographical distribution.—This form is widely distributed in Kashgar and the neighbouring regions (*vide* Weber). We have examined a large series of specimens, some of which agree well with Weber's figures, from a swamp near Gandarbal and in road-side ponds between Ichabal and Martand in Kashmir.

The form occurs in areas of still water full of aquatic vegetation.

Form **costulata** Martens.

1874. *L. lagotis* var. *costulata*, Martens, *op. cit.*, p. 26, pl. ii, fig. 24.
1878. *L. lagotis* var. *costulata*, Nevill, in Hume's *Sec. Yarkand. Miss. Moll.*, p. 8.

This form differs from the preceding chiefly in its longer spire. The shape of the mouth of the shell is more constant and never so expanded as in some specimens of the form *striata*. The spire is somewhat variable and in some shells is relatively long, especially in dorsal view.

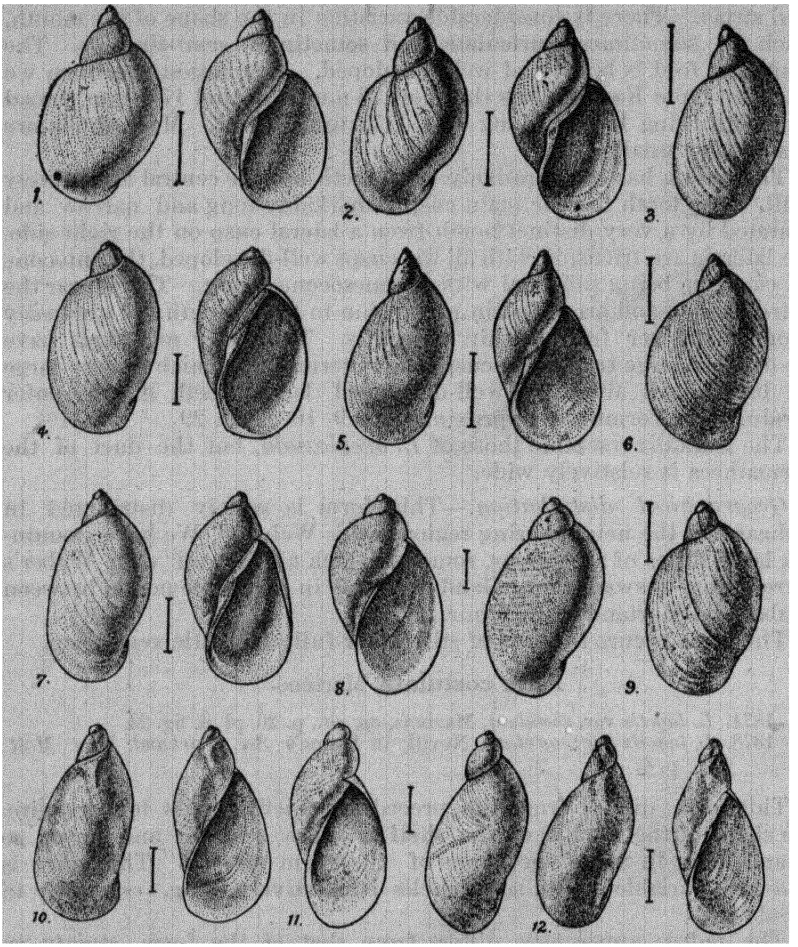
The radula apparently differs from that of the form *striata* in that the laterals are still larger and broader and that the teeth of the marginals are fewer and rather less well-developed.

Geographical distribution.—The form was described (in Russian) from Turkestan. We have examined a large series of specimens from Leh in Ladak and from the Wurdwara valley, (8,500 ft.) in Kashmir, also several recently obtained by Mr. G. H. Tipper of the Geological Survey of India, in marshy ground near the village Harchin in Chitral at an elevation of about 9,000 ft. Some of the shells from the last named locality resemble var. *albipicta* of Martens in the work cited (pl. ii, fig. 23).

Form **solidissima**, Kobelt.

1872. *Limnaea lagotis* var. *solidissima*, Kobelt, *Malak. Blatt.*, XIX, p. 76, pl. ii, figs. 17, 18
1877. *Limnaea lagotis* var. *solidissima*, *id*., *op. cit*., pl. 128, fig. 1242.
1878. *Limnaea lagotis* var. *solidissima*, Nevill, *op. cit*., p. 7.

This appears to be an abnormal form with a very thick shell but otherwise of extreme variability. It probably lives in water of



1. *Limnaea shanensis*.
2. *Do*.
3. *Do*.
4. *L. shanensis* f. *kehoensis*.
5. *L. shanensis* f. *superstes*.
6. *L. shanensis* f. *kehoensis*.
7. *L. shanensis* f. *kehoensis*.
8. *L. horae* f. *ultior*.
9. *L. shanensis* f. *kehoensis*.
10. *L. mimetica*.
11. *L. horae*.
12. *L. mimetica*.

abnormal chemical composition. The shell is never very large but is often relatively broad and with a very short spire. The peristome is exceptionally well-developed, but the columellar fold has never the peculiar shape or porcellaneous consistency of that of

L. obliquata Martens, which is otherwise closely similar in shell characters. The largest specimen we have examined is 22 mm. long and 14·5 mm. broad, the mouth being 15 mm. long and 10 mm. broad.

We have no information as to the radula or the genitalia.

Geographical distribution.—The form was described from the Himalayas and we have examined a few small specimens from Kashmir as well as the large series from Lake Pankong on the Pamirs recorded by Nevill (*op. cit.*).

Form **subdisjuncta** Nevill.

1878. *Limnaea lagotis* var. *subdisjuncta*, Nevill, *op. cit.*, p. 9.

This is a small form with a relatively narrow shell and a rather elongate spire of which the scalariform structure is peculiarly well marked. The base of the spire is considerably narrower than the upper margin of the body-whorl. The shape of the mouth differs somewhat in different specimens, but is never much expanded. The columellar fold is not at all well-developed. The largest specimen we have examined is 11·5 mm. long and 7 mm. broad, with the mouth 8 mm. long and 5 mm. broad. The surface of the shell is covered by a blackish deposit in the type-series.

Possibly this form should be regarded as a distinct species, but some of the shells approach those of the form *striata*. We have not seen either the radula or the genitalia.

Geographical distribution.—The type-series still in the Indian Museum, is from Leh in Ladak. Weber (*op. cit.*, pl. i, fig. 10 *g*) has figured a specimen from somewhere in Central Asia, but we are doubtful whether this shell really belonged to the form. Its peculiarities seem to have been due to some interference in the growth of the shell and the shape of the mouth differs from that of any specimen in the type series.

Form **bactriana** Hutton.

1850. *Limnaea bactriana*, Hutton, *Journ. As. Soc. Bengal*, XVIII (2), p. 656.
1919. *Limnaea bactriana*, Annandale and Prashad, *Rec. Ind. Mus.*, XVIII, pp. 40, 42, 45, figs. 5-A, 6-E ; v, figs. 1, 2 ; pl. vii, fig. 6.

A comparison with other forms of *L. lagotis* convinces us that this form must be included in the species. The mouth is relatively shorter than in the other Indian forms, approaching that of the *forma typica* in this respect, but the basal whorl of the spire seems to be broader and lower than in European specimens. The form has been fully described by Annandale and Prashad in the paper cited.

The radular teeth are considerably smaller than in the forms *costulata* and *striata* but the central is relatively larger. The whole radula seems to be narrower than in those forms. In a specimen from Mesopotamia the formula is 16. 11. 1. 11. 16.

L. lagotis var. *compressa*, Andreae from Central Asia seems, to judge from Weber's figure (*loc. cit.*, fig. 10 *e*), to be very similar, but perhaps the shell is a little narrower.

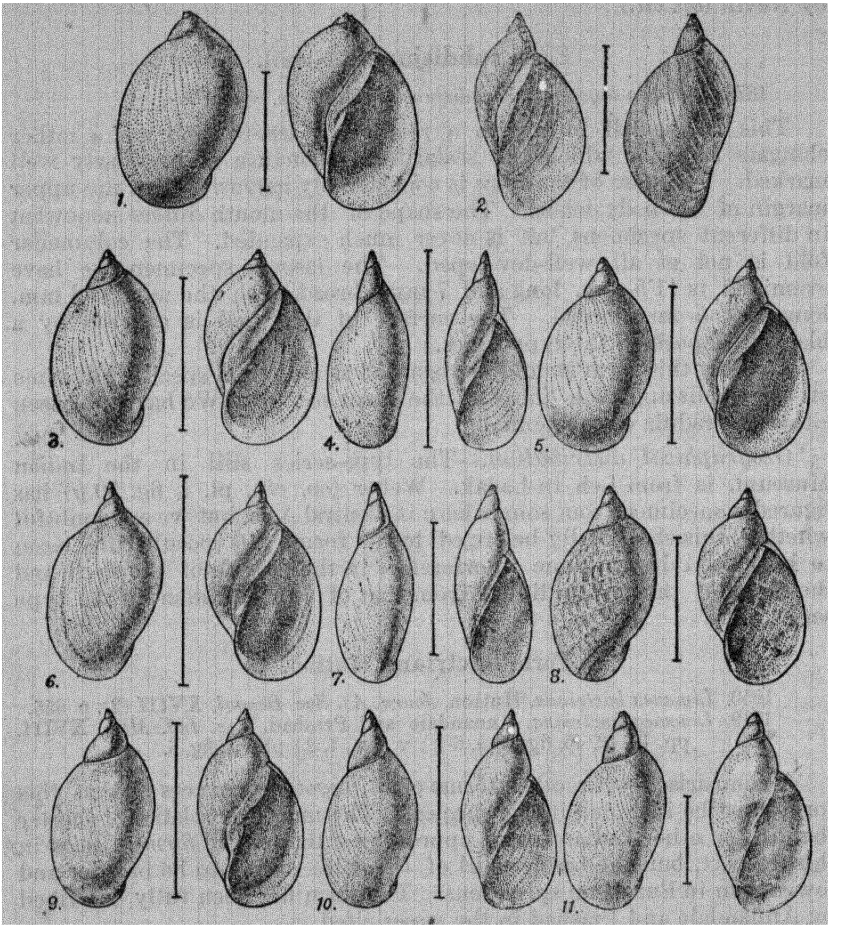
Geographical distribution.—The range of the species extends from Central Afghanistan to Seistan and S. Iraq.

The form occurs in permanent ponds and pools, amongst dense vegetation.

Form **defilippii**, Issel.

1865. *Limnaea defilippii*, Issel, *Catalog. Moll. Miss. Ital. in Persia*, p. 45, pl. iii, figs. 62, 63.

This form resembles f. *subdisjuncta* in its general shape, but there is usually an extra whorl in the spire and the shell is larger and more fragile and highly polished on the surface. The largest shell we have



1. *Limnaea acuminata* f. *brevissima*.
2. *L. biacuminata*.
3. *L. acuminata*.
4. *L. acuminata* f. *gracilior*.
5. *L. acuminata*.
6. *L. acuminata* f. *chlamys*.
7. *L. acuminata* f. *gracilior*.
8. *L. acuminata* f. *malleata*.
9. *L. acuminata* f. *patula*.
10. *L. acuminata* f. *rufescens*.
11. *L. acuminata* f. *hians*.

seen is 17·5 mm. long and 10 mm. broad with the mouth 12 mm. long and 6·5 mm. broad.

Nevill, who regarded *f. defilippii* as distinct, has described a form *sirikulensis*, which has a larger, broader and thicker shell than the true *defilippii*. The surface of the shell is dull and malleated.

The radular teeth are intermediate in size between those of f. *bactriana* and those of the other forms we have examined. They seem to be less numerous in each transverse row than in any of these forms. The laterals are relatively short and broad, and the formula in a specimen from Kashmir is 16. 8. 1. 8. 16.

The genitalia are of the usual type. The penis is slender and approximately equal to that of the distal part of the penis-sac. The spermatheca has a long duct, and the two together are approximately equal to the uterus in length.

Geographical distribution.—The form *defilippii* was originally described from Lake Goktscha (5,500 ft.). We have examined a large series of specimens from Kukar Nag in Kashmir which agree with Issel's figure and descriptions fairly well.

The form occurs in rice-fields in Kashmir.

Limnaea brevicauda Sowerby.

1873. *Limnaea brevicauda*, Sowerby in *Reeve, op. cit.*, XVIII, Sp. 105, pl. xv.
1876. *Limnaea brevicauda*, Hanley and Theobald, *op. cit.*, p. 64, pl. 158, fig. 7.

This is an inflated short-spired lacustrine *Limnaea* which we were at first prepared to regard as an extreme form of *L. lagotis*. It has been confused with *L. auricularia* from which it differs not only in the structure of the spire but also in that of the jaw, radula and genitalia. The spire has 3 whorls and there is a distinct but narrow canal outside the suture at its base. The body-whorl is always much inflated but the spire never completely sinks into it as in some forms of *L. auricularia*. The columellar fold is much twisted, fairly broad in the region of the umbilicus but disappears below this point. It has not the porcellaneous texture of that of *L. obliquata*. The largest shell we have seen is 19 mm. long, and 16·3 mm. broad with the mouth 16 mm. long and 11·5 mm. broad. The shell is rather fragile and has a translucent luteous colour when fresh. The surface is smooth and polished with numerous very fine close-set striae.

The radula is remarkable for the very large size of the teeth, which are also numerous in the transverse series. Some of the laterals are occasionally bicuspid but this is a mere abnormality, which is never present in the first lateral. The cusp of the central, which is relatively very small, is almost bilaterally symmetrical. The laterals are relatively long and narrow with elongate sharply pointed mesocones and much shorter ento-and ectocones. These two latter are subequal in the first lateral. The free edge of the inner marginals, which are relatively broader than the laterals is transverse and has five to six teeth of which the outermost is much the broadest. There are two or three small teeth on the outer margin. The outer marginals are narrow and simple in structure with three terminal teeth. They are much less asymmetrical than in many forms.

The genitalia closely resemble those of *L. lagotis* form *striata*, but the spermatheca and its duct appear to be much narrower and the epiphallus is slightly shorter. These characters, however, may be seasonal.

Geographical distribution.—This is one of the commonest molluscs in the lakes of the Kashmir valley, to which the species is perhaps confined. The type-specimen was stated by Sowerby to come from Australia but the error was demonstrated long ago by Blanford.

The species is found in slow-running streams issuing from springs with a sandy or shingly bottom. In Kashmir the species has been found in large numbers in streams round about Ichabal and in the Chinar-Bagh nullah near Srinagar. Members of the species seem to have a preference to stones and sand and are usually found crawling on them, though aquatic plants are found in abundance in the streams. They apparently feed on minute algae growing on stones and other hard objects.

Limnaea auricularia (Linn.)

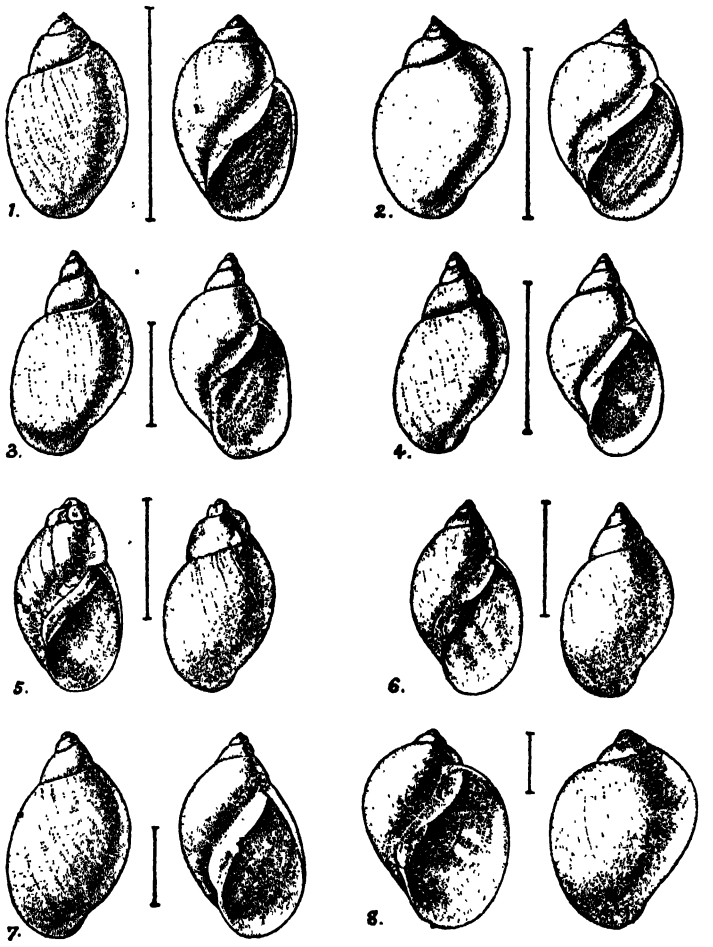
1805. *Limneus auricularius*, Draparnaud, *Hist. Nat. Moll. France*, p. 49.
1870. *Limnaea auricularia* var *ventricosa*, Martens, *Malakoz. Blätt.*, p. 152, pl. iii, fig. 8.
1877. *Limnaea auricularia* var *ventricosa*, Kobelt in Rossmässler's *Icon. Land Süss Moll.*, V, p. 40, pl. 129, fig. 1244.
1910. *Limnaea (Gulnaria) auricularia* var *ventricosa*, Weber *Zoologisch. Jahrb.*, XXIX, p. 501.

This common European species, which also occurs in Kashmir, is easily distinguished from all the true Indian forms of the genus by its short acuminate spire, and very oblique and greatly inflated body-whorl. It is, however, liable to be confused with two related species found with it in Kashmir, namely, *L. lagotis* and *L. brevicauda*. From both of these it can be distinguished when the spire is complete by the fact that its suture is linear, whereas in the other two species the suture is so broad that the spire has a scalariform appearance. The spire, however, is often eroded and, if this is so, the structure of the columella and its callus provides a sure means of diagnosis. In *L. auricularia* the columella is very strongly twisted and appears as a broad fold which occludes the umbilicus. This fold, however, is not continued down the inner lip to the anterior margin, but disappears a short distance in front of the umbilicus. In the other two species the columella is not so strongly twisted and its fold is continued down the lip, disappearing gradually near the anterior margin. When *L. auricularia* is found together with *L. brevicauda*, as sometimes happens in Kashmir, these differences, once they have been detected, become very clear. The largest shell we have seen is without the spire and is 21 mm. long, 17 mm. broad, with the mouth 19 mm. long and 11·5 mm. broad.

Another similar form, so far as the shell is concerned, is the Central Asiatic *L. obliquata* Martens. In this species, of which we have examined specimens from Issik-Kul the columellar fold has a very peculiar character. In outline it is not unlike that of *L. auricularia*, but it is greatly thickened and almost tubercular and has a porcellaneous consistency instead of being merely a thin lamella.

The jaw in the Indian specimens of *L. auricularia* we have examined differs considerably from Baker's figure (*op. cit.*, pl. vi, fig. D.); for instead of there being a projection in the middle of the free margin there is a well-defined excavation.

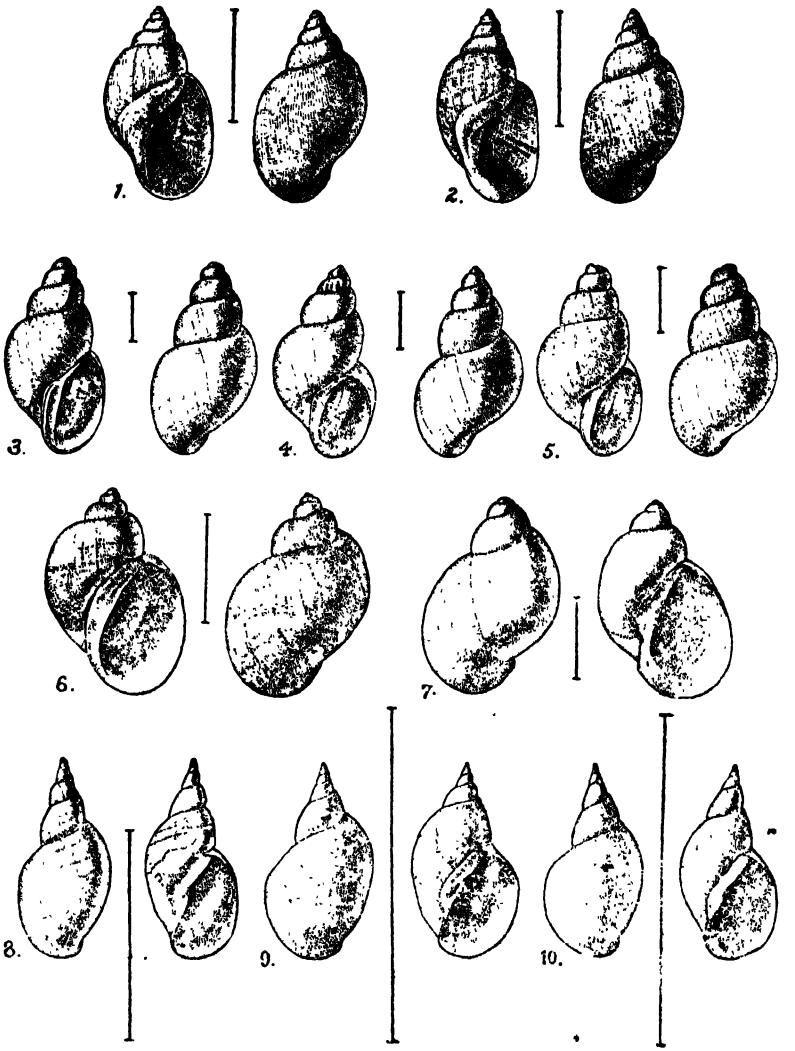
The radular teeth are large and elongate as in *L. brevicauda*, but the cusps are comparatively long and stout, and the mesocone is much



1. *Limnaea luteola.*
2. *L. luteola* f. *ovalis.*
3. *L. luteola* f. *australis.*
4. *L. luteola* f. *succinea.*
5. *L. luteola* f. *siamensis.*
6. " "
7. *L. luteola* f. *impura.*
8. *L. physcus.*

larger as compared with the ento-and ectocones and has a more lanceolate appearance. The central is relatively shorter and stouter than in *L. lagotis* f. *striata*, and differs from that of *L. brevicauda* in having a small lateral cusp on the right side. The formula is approximately 19. 9. 1. 9. 19. Baker's figure (*op. cit.*, pl. vii, fig. C) of the radula of this species was evidently drawn from a specimen in which several of the laterals were abnormal having the entocone more or less completely suppressed. Our preparations agree fairly well with Hazay's figure of European specimens of this species (*Malakoz. Blatt.* (n.s.) VII, pl. i, fig. 1, 1885).

In the genitalia the most noteworthy features are that the duct of the spermatheca is even longer than in other Indian forms, considerably exceeding the uterus in length. The prostate is definitely pear-shaped and the vas deferens issues from a depression on its ventral surface considerably above the distal extremity. The distal part of the penis-sac has a more or less well-defined constriction a short distance below its upper extremity. In all these points our preparations agree with Baker's figure (*op. cit.*, pl. x, fig. C).



1. *Limnaea laticallosa.*
2. Do.
3. *L. truncatula.*
4. Do.
5. Do.
6. *L. bowelli.*
7. *L. hookeri.*
8. *L. stagnalis* f. *minor.*
9. *L. stagnalis* f. *kashmiriensis.*
10. Do. do.

Geographical distribution.—The species is distributed over the greater part of the Palaearctic region and has been introduced artificially into green-houses in North America. The only Indian species of which we know are from the valley of Kashmir.

The species is found in the shallower regions of slow streams with thick vegetation and near the shore of lakes overgrown with aquatic plants. In Kashmir it has been found on the shores of the Wular and Dal lakes and in large numbers in streams issuing out of these lakes, or in shallow channels between floating islands. Living animals were nearly always found on the leaves of aquatic plants on which apparently they feed.

Shells from Kashmir are referred by Weber to the form *ventricosa*, Hartmann, but our specimens do not altogether agree with Kobelt's figures in Rossmässler's *Icon.* We have very little European material for comparison and do not feel justified in referring them to any of the numerous described forms of the species to which we are strongly convinced they belong.

Galba Schrank.

1911. *Galba* (in part), Baker, *op. cit.*, p. 199.

We use the term *Galba* in a much more restricted sense than Baker (*op. cit.*), confining it to *L. truncatula* and its allies, all of which can be distinguished by the great development of the columellar fold of the shell.

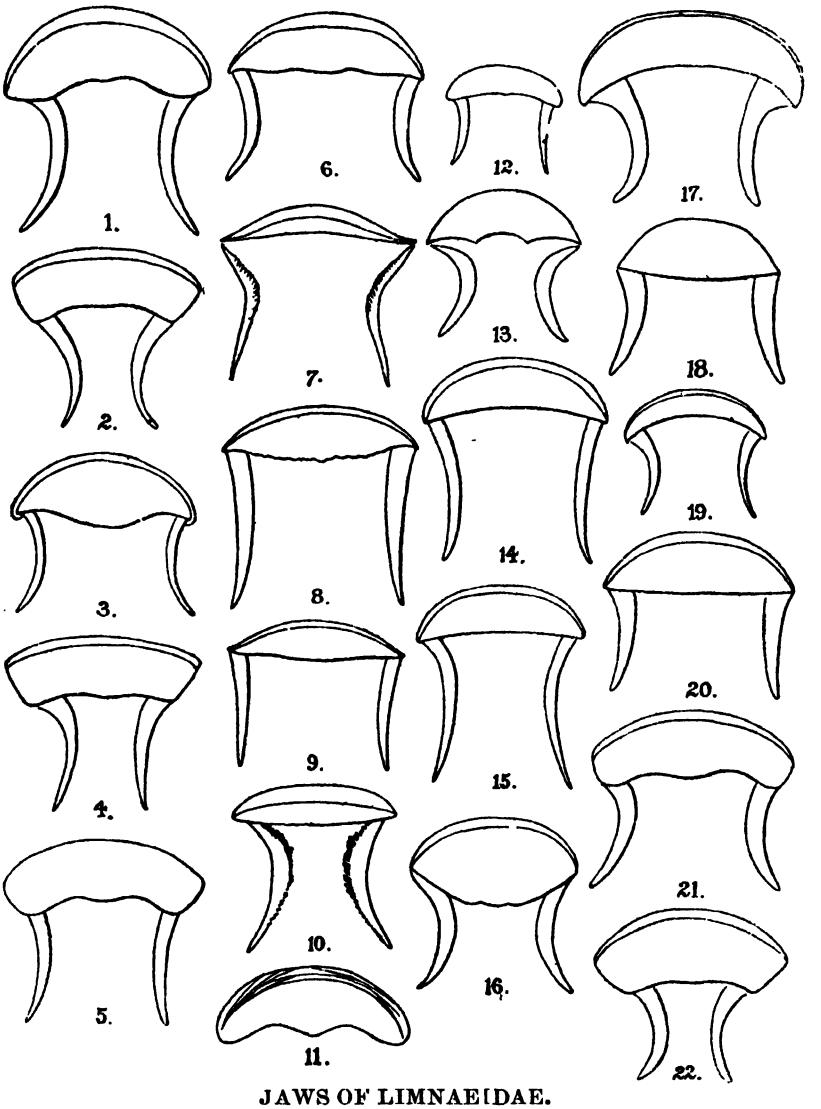
This is probably another Palaearctic group that has penetrated into the confines of the Indian Empire from the North and West. The distribution of its species is, however, anomalous and the right to three of the six we include to a place in the Indian fauna is not confirmed. The type-species (*L. truncatula*) has been rightly recorded from Ladak and occurs in Indian territory, also at high altitudes in Chitral, for most previous records are, however, due, in our opinion, to confusion with the closely allied *L. andersoniana*, the range of which extends from Eastern China on the one hand into Upper Burma and the Manipur valley, and on the other into Kashgar and the Upper Indus valley. The three species of which the inclusion in one fauna is doubtful are *L. hookeri* and *L. bowelli* which are only known from the northern watershed of the Himalayas in Tibet, and *L. hordeum*, which was originally described from Iraq and has been rediscovered in Seistan and in the Afghan desert near the Perso-Baluch frontier. The sixth species of the group to be considered has been described by us in a paper we published recently on the aquatic gastropods of the Inlé watershed. So far as we know, its range is restricted to a small area in the Shan Plateau.

Limnaea truncatula (Muller).

1805. *Limneus minutus* Draparnaud, *Hist. Nat. Moll. France*, p. 53, pl. iii, figs. 5—7 ; (Tableau, p. 51, 1801).
1862. *Limnaeus truncatulus* Kuster in *Martini & Chemnitz, Limnaea.*, I, abth. 17 B, p. 17, sp. 21, pl. iii, figs. 24—27.
1873. *Limnaea truncatula* Sowerby in Reeve's *Con. Icon.*, XVIII, sp. 3, pl. i.
1878. *Limnaea truncatula* (in part) Nevill, *Results. Sec. Yark. Miss.*, p. 10.

This species seems to run into *L. andersoniana* in a very interesting manner, which we discuss below (p. 133). It is convenient, however, to regard it as distinct for purposes of classification.

A few shells of *L. truncatula* were collected by Stoliczka at Leh in Little Tibet along with a large number of examples of *L. andersoniana*



JAWS OF LIMNAEIDAE.

1. *Limnaea acuminata* f. *patula*.
2. Do. * do.
3. *L. acuminata*.
4. *L. luteota* f. *siamensis*.
5. *L. luteola* f. *impura*.
6. *L. andersoniana*.
7. *L. horae*.
8. *L. shanensis* f. *superstes*.
9. *L. mimetica*.
10. *L. lativallosa*.
11. *L. bowelli*.
12. *Limnaea truncatula*.
13. *L. auricularia*.
14. *L. luteola* f. *ovalis*.
15. Do.
16. *L. persica*.
17. *L. brevicauda*.
18. *L. biacuminata*.
19. *L. peregra*.
20. *L. iranica*.
21. *L. stagnalis* f. *Kashmiriensis*.
22. *L. persica*.

* Lateral pieces omitted in the drawing.

with which he confused them. Nevill recorded in his Hand-List shells from Kulu, Kotgarh and Leh under *L. truncatula*, but we find on an examination of the specimens that all except a few from Leh are referrable to *L. andersoniana*.

Shells of this species from Leh are more or less typical but one of them agrees with Martens' figure of *L. truncatula* var *longula* in Fedtschenko's *Reise in Turkestan* (pl. ii, fig. 26) except that it has the aperture more expanded.

The only other known occurrence of this species within Indian limits is due to Mr. G. H. Tipper of the Geological Survey of India, who recently obtained a few shells from marshy ground near the village Harchin in Chitral at an altitude of 9,000 feet. One of the shells agrees with Martens' figure in the work cited except that the mouth is less expanded. The remaining shells are much smaller and have a relatively small and narrow aperture.

This is a mud-loving form and is practically amphibious in habits.

Limnaea andersoniana, Nevill.

1878. *Limnaea truncatula*, Nevill, *o.p. cit.*, p. 10.
1881. *Limnaea andersoniana*, Nevill, *Journ. As. Soc. Bengal*, I (2), p. 142, pl. V, fig. 9.
1918. *Limnaea andersoniana*, Annandale *Rec. Ind. Mus.*, XIV, p. 106, pl. x, figs. 1, 2.
1919. *Limnaea truncatula* Annandale and Prashad, *op. cit.*, p. 50.
1921. *Limnaea andersoniana*, Annandale and Prashad, *Rec. Ind. Mus.*, XXII, p. 574, pl. viii, figs. 1-6.

This species differs from any we have as yet discussed in its extreme plasticity. Individual variability is as a rule, however, by no means pronounced. The main environmental factor in its plasticity is as a rule apparently the flow of water, for we can define three well-marked phases, one of which lives in still water, one in ordinary hill-streams and one in rapid-running mountain torrents. We are acquainted also with a fourth phase intermediate between the first two and, in one instance, inhabiting a pond into which a stream flows at certain seasons, but the characters of this phase are much less definite. We propose for it the name *intermedia*. The pond form is the *forma typica*, while the stream form has already received a name (*simulans* Preston). We propose for the torrent form the name *turbinicola*.

The great difficulty we experience in describing *L. andersoniana* is that it approaches in its running-water phases very close to *L. truncatula*, from which the *forma typica* seems to be quite distinct. We will discuss this point at the end of our notes on the species.

The shell is distinguished primarily by the following characters :—

(1) The possession of a very coarse broad and moderately elongate columellar fold, which completely occludes the narrow umbilicus but stands out over it in such a way that a passage leading to the umbilicus is left open on the dorsal surface of the shell.
(2) The more or less elongate-ovate shape of the shell.
(3) Its comparatively small size (height not exceeding 12 mm. and maximum diameter 6 mm.).

(4) The slight flattening of the upper margin of the whorls outside the suture.
(5) The very slight obliquity of the suture and its linear structure.
(6) The fact that the spire is never so long as the body-whorl as seen in dorsal view.

The colour and texture of the shell vary considerably in different localities, but it is never very fragile and never dark. The surface is never very highly polished.

The differences in the shell are well shown in the work cited last.

The jaw offers no startling peculiarity. The mandible forms a segment or sector of a circle less than a semi-circle and the free border is slightly sinuate. The side-pieces are strongly curved and shorter than in some species.

The radula raises the interesting question, How far is the form of radular teeth to be regarded as of real taxonomic value? It will be simplest to describe radulae of three different types separately.

The first type is that of specimens of the *forma typica* from the neighbourhood of the Inlè Lake in the Southern Shan States. The formula is approximately 18. 10. 1. 10. 18. The teeth are comparatively short and broad. The central is relatively large with a sharp, well-defined cusp on one side of the main cusp. The inner laterals have three well-developed cusps, the ectocone and the entocone being subequal, but the latter is situated on the side of the mesocone much further from the base than the former. The outer laterals or intermediate teeth have four to five cusps in addition to an outer marginal denticulation or pair of denticulations representing the reduced ectocone. The marginals are very similar but grow gradually narrower from within outwards.

The second type is that of specimens of the form *simulans* from streams in the same district. The teeth are perhaps a little more numerous and distinctly larger and longer in proportion to their breadth. The basal denticulations of the outer laterals and the marginals are better developed, but otherwise there is no structural difference.

The third was found in the radula of a specimen from a series of intermediate shells from the Simla Hill States. Unfortunately we have succeeded in extracting only this one radula. It differs from those of Shan specimens in (*a*) the obsolete condition of the entocone, which is reduced to a mere projection in all the first lateral and is only a little bigger in the outer members of this series and (*b*) in the deeper cleft between the meso-and ectocones of these teeth. The marginals also have a greater tendency to assume monstrous forms. As we shall see later this radula exhibits a close resemblance to that of *L. truncatula*.

The genitalia of *L. andersoniana* are also very like those of *L. truncatula*. The spermathecal duct is a little longer than the uterus and seems to have a permanent curvature just below the spermatheca. The prostate is heart-shaped and the vas deferens issues from it near the pointed distal end. The penis is very slender and distinctly shorter than the distal part of the penis-sac.

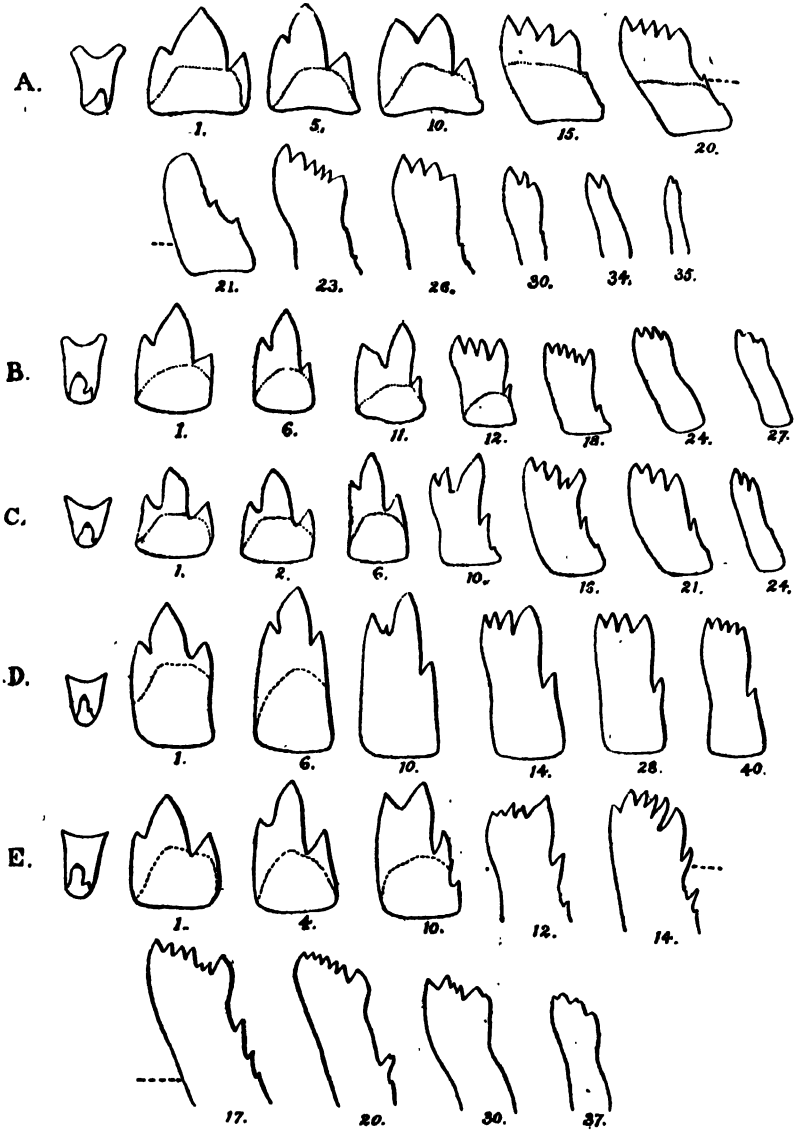
Geographical distribution.—*L. andersoniana* is common in the Chinese province of Yunnan, in the Southern Shan States and in the Manipur valley. It also occurs in the Nepal valley, in the Kangra valley, in Ladak and in the Simla Hill States on the Himalayas, and in Kashgar. It appears thus to be always or almost always an inhabitant



RADULAR TEETH OF LIMNAEIDAE.

A. *Limnaea stagnalis f. kashmirieusis.*
B. *L. stagnalis f. minor.*
C. *L. auricularia.*
D. *L. brevicauda.*

of mountain valleys. The common form in Yunnan is *simulans* while the specimens we have examined from the Western Himalayas and neighbouring districts belong more or less definitely to the form *intermedia* which also occurs in Assam near the base of the Naga Hills. The form *turbinicola* is only known from the hills on the western side of the Manipur valley, but the form *simulans* probably occurs in all eastern districts in which the *forma typica* is found.



RADULAR TEETH OF LIMNAEIDAE.

A. *Limnaea persica.*
B. *L. lagotis* f. *bactriana.*
C. *L. lagotis* f. *defilippi.*
D. *L. lagotis* f. *costulata.*
E. *L. lagotis* f. *striata.*

We may now discuss the relationship between *L. andersoniana* and *L. truncatula*. We have seen shells from Chitral on the north-west frontier which can be definitely assigned to the latter species, and specimens of *L. andersoniana* from the extreme north-west of India do not approach it any closer than those of the form *simulans* from the Southern Shan States. The two species, however, granted that they are distinct, resemble one another closely in shell structure, particularly in the form and texture of the columellar fold and in the direction and character of the suture, and the adjacent part of the whorls. So far there is nothing to prevent the two species from being regarded as quite distinct, though closely allied. This view is also borne out by comparison between the genitalia of the forma typica of *L. andersoniana* and those of typical European specimens of *L. truncatula*. An examination of the radula of the different forms concerned, however, renders the problem much more complex. We find that the teeth of the *forma typica*, or at any rate of individuals of this form from the Southern Shan States, do not possess the characteristic features of those of *L. truncatula*. If, however, we examine the radula of individuals of the form *simulans* from the Southern Shan States we find a distinct approximation to the *truncatula* type, while in individuals of the f. *intermedia* from North-west India the similarity is much greater amounting indeed, if sufficient allowance is made for individual variation, to a practical identity. The explanation may be as follows, but we offer it tentatively.

L. andersoniana has become differentiated from *L. truncatula* on or near the north-west frontier of India, probably in the upper waters of the Indus. Here some factor induced great variability of the shell, which, however, became more different from that of *L. truncatula* than did the radula. In the eastern parts of the range of *L. andersoniana* the form *simulans* became more clearly differentiated from the forma typica, probably in direct correlation with a greater differentiation of environment in the same localities than was to be found in the mountain valleys near the head waters of the Indus and the Jumna. The form *simulans* which retained the amphibious habits of *L. truncatula* most distinctly underwent comparatively little change so far as the radula was concerned, whereas the pond-living *forma typica* underwent considerable change in this respect.

Unfortunately we have not been able to examine the radula of individuals of the form *intermedia* from Manipur. It is possible that they are reversions to an ancestral type in a strict sense and that their radula will be found on examination to agree with that of individuals from the north-west, but whether this is so or not can only be proved by an actual examination of specimens.

Limnaea hookeri Reeve.

1850. *Lymnaea hookeri*, Reeve, *Proc. Zool. Soc.*, XVIII, p. 49.
1873. *Limnaea hookeri*, Sowerby in Reeve *Con. Icon.* XVIII Sp. 74, pl. xi.
1909. *Limnaea hookeri*, (in part) Preston, *Rec. Ind. Mus.*, III, p. 115.
1915. *Limnaea* (*Gulnaria*) *hookeri*, *id.*, *Faun. Brit. Ind.*, Moll., p. 111

The shell is of moderately small size, not exceeding 12 mm. in height and 8 mm. in maximum diameter. It is of a rather broad ovoid shape, minutely blunted at the apex. In many points it closely

resembles the shell of *L. andersoniana* (p. 38). The following characters are diagnostic :—

(1) The upper margins of the whorls are rather broadly flattened outside the suture.
(2) The suture is very oblique, especially just above the body-whorl.
(3) The columellar callus is very thick and almost procellaneous.
(4) The umbilicus, though covered by the fold of the columella in ventral view, is conspicuously present in lateral view.



RADULAR TEETH OF LIMNAEIDAE.

A. *Limnaea bowelli.*
B. *L. hookeri.*
C. *L. iranica.*
D. *L. gedrosiana.*
E. *L. peregra.*

In other respects the shell is not unlike that of the widely distributed Palæarctic *L. peregra* in its form *ovata*.

The radula differs from that of all other Indian or Southern Palæarctic species (with the exception of some specimens of *L. andersoniana*) so far as they are known, in the fact that the entocone of the first lateral is reduced to a slight projection, the other teeth of the same series being distinctly tricuspid, at any rate for several longitudinal rows. Those of the sixth row in the only specimen examined have lost the entocone, but this is probably abnormal, as the cusp is well developed in subsequent rows. The mesocone of all the laterals is fairly long, sharply pointed and rather narrow. In the intermediate teeth it often assumes a more or less monstrous form and finally becomes broken up into several smaller cusps. The transition from laterals to marginals is gradual. The latter have a transverse series of four or five fairly stout cusps, of which the outermost, representing the mesocone, is the largest, and also one or more comparatively long narrow cusps on the outer margin. We cannot give the dental formula exactly, as our radula extracted from a dried specimen is incomplete. There are 11 laterals and at least 9 marginals.

Geographical distribution.—It is doubtful whether *L. hookeri* occurs actually within the limits of the Indian Empire. Hooker discovered the original specimens according to Reeve, "on the Thibetian or north side of Sikkim Himalaya, at 18,000 feet elevation." Major F. H. Stewart found the species not uncommon in Eastern Tibet at altitudes from 13,000 to 14,000 feet.

Habits.—Major Stewart obtained his specimens in a pond which dried in winter, in a stream from a hot spring and in marshy pools. Spawn was observed in February and March.

Limnaea bowelli Preston.

1909. *Limnaea bowelli*, Preston, *Rec. Ind. Mus.*, III, p. 115.

This species was described from an immature shell or shells only 8·5 mm. high. We recently received a large specimen from Major F. M. Bailey, who took it at a height of 16,000 feet in Southern Tibet. This specimen is 15·5 mm. high and 11·0 mm. broad and differs in several particulars from the type, coming very close to some shells of *L. hookeri* but differing from them in its impressed suture and much wider umbilicus. It is of a fairly dark chestnut colour.

The radula differs greatly from that of *L. hookeri*, the first laterals in particular being tricuspid. Other differences are to be found in the figures. According to Bowell as quoted by Preston "the maxilla is also very remarkable with a large blunt beak arising from the centre ot the semicircular piece." Our own preparation hardly shows a structure so peculiar, but there is a definite projection on the posterior margin of the jaw, a little more pronounced than in any other species we have examined.

The genitalia offer no great peculiarities.

Geographical distribution.—The species has not been found within Indian limits but seems to be fairly common in the Gyantse valley in Tibet and the neighbouring districts. Major Bailey's specimen is from

Tratsang (16,000 feet). The species often occurs in warm springs. It has been found at altitudes between 13,120 and 16,000 feet.



RADULAR TEETH OF LIMNAEIDAE.

A. *Limnaea laticallosa.*
B. *L. andersoniana.*
C. *L. andersoniana* f. *simulans.*
D. *L. andersoniana* f. *intermedia.*
E. *L. truncatula.*

Limnaea hordeum Mousson.

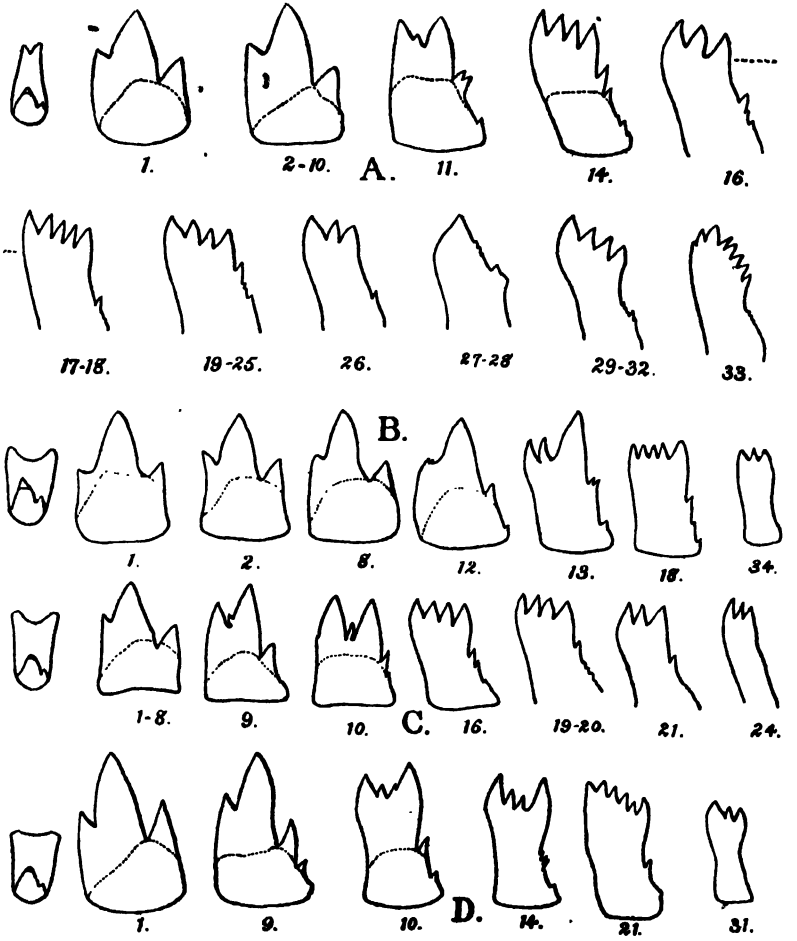
1874. *Limnaea hordeum* Mousson, *Journ. Conchyl.* XXII, p. 42.
1919. *Limnaea hordeum* Annandale & Prashad, *op. cit.*, p. 51, pl. vii, fig. 5, and p. 114, pl. xiv, figs. 4, 5.

This curious little species which is only known from the shell, differs from *L. truncatula* chiefly in its more rounded whorls, more oblique suture, thicker lip, and less well developed columellar fold.

Specimens have been found on the shores of the lower Euphrates, in flood debris in Seistan, and at the edge of Gaudi-i-Zirrreh, the great salt pan in the Afghan-Baluch desert. All these shells may have been subfossil.

Limnaea laticallosa Annandale & Rao.

1925. *Limnaea laticallosa* Annandale & Rao, *Rec. Ind. Mus.*, XXVII, p. 105.



RADULAR TEETH OF LIMNAEIDAE.

A. *Limnaea luteola.*
B. *L. luteola* f. *australis.*
C. *L. luteola* f. *oralis.*
D. *L. ovalior.*

Pseudosuccinea Baker.

1911. *Pseudosuccinea*, Baker, *op. cit.*, p. 162.

The great majority of the true Indian and Burmese species belong to this group, which is also well represented in Europe (by forms of *Limnæa peregra* or very closely allied species) in North America and

throughout practically the whole of Asia. In peninsular India *Pseudosuccinea* was established as early as the late Cretaceous epoch. The form *L. oviformis* very closely related to the living *L. luteola* was found by Hislop in the Intertrappean beds of the Central Provinces. It is thus possible that the group originated in India, but the Indian species are closely related to the Palaearctic *L. peregra* through several forms peculiar to or characteristic of Baluchistan and Eastern Persia. Resemblances are to be found not only in the shell but also in the radulae and genitalia.

Limnaea iranica Annandale & Prashad.

1919. *Limnaea iranica*, Annandale & Prashad, *op. cit.*, p. 43, pl. vii, fig. i and p. 42, fig. 6F.

This species and its ally, *L. gedrosiana*, form links between the characteristic Indian *L. acuminata* and the European members of the *peregra* group. *L. iranica* has been fully described by Annandale and Prashad. The shell is very like that of smaller forms of *L. acuminata*, but the outer margin of the lip is more convex and forms a regular curve.

The jaw differs from that of *L. acuminata* in having a straight instead of a sinuate posterior margin.

The radula is very close to that of European specimens of *L. peregra*, but is distinguished by the more oblique and more profusely denticulated cutting margin of the marginals. The denticulation of the inner members of this series is indeed very characteristic and distinguishes the species from *L. acuminata*. In all these forms the cusp of the central is very asymmetrical, the projection on the left having disappeared completely.

Geographical distribution.—We have examined specimens collected by Blanford in Persian Baluchistan and at Magas in Southern Persia.

Limnaea gedrosiana Annandale & Prashad.

1919, *Limnaea gedrosiana*, Annandale & Prashad, *op. cit.*, p. 48, pl. vii, figs. 2—4 ; p. 42, text, figs. 6A and Б, p. 107.

This species has also been recently described by Annandale and Prashad. It is still more closely related to *L. peregra* than *L. iranica*, but the shell is narrower as a whole and has the arc of the lip somewhat flattened above. The spire is also, as a rule, longer and the mouth projects further below the umbilicus.

The radula differs from that of *L. iranica* in having fewer denticulations on the inner marginals. From that of *L. peregra* it only differs in having the teeth somewhat stouter and larger, possibly also the marginal and lateral series are a little shorter. The formula for a specimen from Persian Baluchistan is 18.7.1.7.18.

Geographical distribution.—The species was originally described from near Kerman in Eastern Persia and has since been found in lakes near Nushki in the Baluch-desert. Quite recently Dr. S. L. Hora obtained specimens in the Punjab Salt Range from Namal on the east side of the Indus.

The species is found in pools and backwaters and is active in very cold weather. It feeds on rotten vegetation and on goat-dung. It often lives in rather saline water.

In the Baluch-desert this species occurred in apparently perennial pools or lakes. Only empty shells were, however, found in winter.

Form **rectilabrum** Annandale & Prashad.

1919. *Limnaea gedrosiana* var *rectilabrum*, Annandale & Prashad, *op. cit.*, p. 49, pl. vi, figs. 1—6 ; p. 40, figs. 5B ; p. 42, figs. 6C, 6D.

This form is distinguished from *L. gedrosiana* by the flattening of the outer lip and its greater variability.

Geographical distribution.—Specimens have been found in the Kushdil Khan reservoir in Baluchistan at an altitude of 5,000 feet, and also in a small pool in the desert south of Nasratabad in Seistan.

This form has been found only in desert pools which are liable to dry up in summer.

Limnaea shanensis Annandale.

1918. *Limnaea shanensis* (phases A to D) Annandale, *op. cit.*, p. 107, pl. x, figs. 5 8 ; pl. xi, figs. 2, 3.

This species represents on the extreme east of the Indian Empire somewhat the same relationship to *L. acuminata* as *L. iranica* and *L. gedrosiana* on the west to *L. peregra*. It is also closely related to *L. yunnanensis* Nevill from Yunnan, but the shell is distinguished from those of both species by its much narrower columellar fold and less acuminate apex, which is, indeed, minutely mamillate. The shell is extremely plastic but two of the three forms with which we are acquainted are only known in subfossil or fossil condition. The shell never exceeds 10·5 mm. in length and 6·5 mm. in breadth and is always thin and fragile.

The radula of the surviving form resembles that of other species in the group but the laterals are distinguished by their quadrate form and relative breadth except in the first lateral. Moreover the mesocone is no longer than the entocone. The dental formula is 20.8.1.8.20.

The three forms may be defined as follows :—

Form **typica** Annandale.

1918. *Limnaea shanensis* (phases A and D), Annandale, *op. cit.*, pp. 107 and 109, pl. x, figs. 5 and 8.

The shell is narrow and has only 3½ whorls. The mouth is somewhat expanded and the lip is slightly sinuate in lateral view. The width of the shell and the length of the spire are somewhat variable. It is found subfossil in the friable clay of the He-ho basin.

The form described by Annandale (*op. cit.*, p. 109) as phase D appears to be only the young of this form.

This was apparently a lacustrine form.

Form **superstes** nov.

1918. *Limnaea shanensis* (phase C), Annandale, *op. cit.*, p 108, pl. x, fig. 7.

This is a still narrower form with the apex composed of a complete whorl. It survives in the Inlé valley, where it is found in the

marginal zone of the Inlé Lake and in ponds amidst dead and growing vegetation.



RADULAR TEETH OF LIMNAEIDAE.

A. *Limnaea acuminata.*
B. *L. biacuminata.*
C. *L. shanensis* f. *superstes.*
D. *L. horae.*
E. *L. mimetica.*

Form **hehoensis** nov.

1918. *Limnaea shanensis* (phase B), Annandale, *op. cit.*, p. 108, pl. x, fig. 6.

The chief characteristic of this form is in its reduction of the spire, the apex being composed of less than half a whorl. We have only found it in a curious deposit of calcareous particles at the head of the He-ho gorge, Southern Shan States, altitude 3,800 feet.

The differences between these three forms are best shown in our figures.

Limnaea physcus Annandale & Rao.

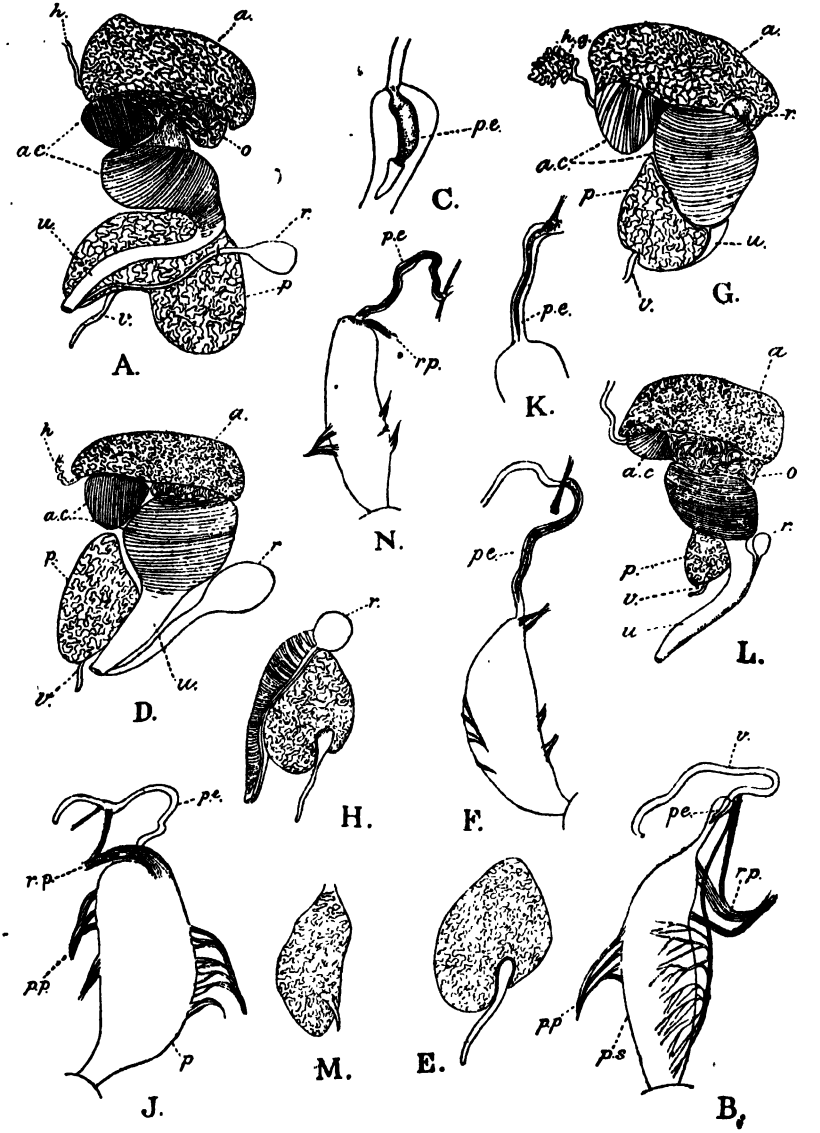
1925. *Limnaea physcus*, Annandale & Rao, *op. cit.*, p. 104.

Limnaea mimetica Annandale.

1918. *Limnaea mimetica* Annandale *op. cit.*, p. 109, pl. x, figs. 9, 9a ; pl. xi, fig. 4 ; p. 175, fig. 9.

The shell of this remarkable form is fully described and well-figured by Annandale. It appears to be a dwarfed race of the

acuminata group and is closely related to *L. shanensis* though distinguished by well-marked characteristics of the jaw, the radula and the genitalia.



GENITALIA OF LIMNAEIDAE.

A-C. *Limnaea stagnalis* f. *kashmiriensis*.
D-F. *L. lagotis* f. *striata*.
G-K. *L. brevicauda*.
L-N. *L. lagotis* f. *defilippi*.
E, H, M. Ventral view of prostate gland.

NOTE.—*a.* albumen gland; *a. c.* accessory albumen glands; *h. g.* hermaphrodite gland; *h.* hermaphrodite duct; *o.* oviduct; *p.* prostate gland; *p. e.* penis; *p.p* protractor muscles of penis; *p. s.* penis sac; *r.* spermatheca; *r. p.* retractor muscles of penis; *u* uterus; *v* vas deferens.

A second collection made at the Inlé Lake in March 1922 proves that the species is a little more variable than is indicated in the original description. Our figures show the extreme range of variation known to us.

The jaw is remarkable for the great relative breadth and shortness of the mandible and for the straightness of the side pieces. The outer margin of the mandible is arched in a slightly sinuous line while the posterior is also slightly sinuate.

The radula is very small even relatively and has only 35 teeth in a transverse row, the formula being 12.5.1.5.12. The teeth differ from those of *L. shanensis* not only in their small size but also in being relatively a little narrower. The marginals are also more curved and the cusp of the central is relatively longer and sharper.

The species is only found amongst dense growing vegetation, particularly *Najas minor*, in very clear water in the Inlé Lake.

Limnaea horae sp. nov.

This species is closely related to *L. mimetica*, but the shell differs (1) in having the spire better developed and broader, with an extra half whorl at the apex, (2) in the complete absence of a columellar callus, (3) in the nature of the sculpture, in which minutely decussated longitudinal striæ, set close together and very numerous, are a conspicuous feature. Some shells, moreover, are distinctly pigmented and of a pale horny colour.

The jaw resembles that of *L. mimetica* in the shortness and breadth of the mandible (a character which is even more accentuated in the new species) and also in the slenderness of the side pieces. They are, however, geniculate inwards instead of being straight, and slightly fimbriated on their inner margin.

The radula is perhaps even less well developed than in *L. mimetica*, the dental formula being the same. The teeth differ in being shorter and broader. The cusp of the central is also considerably smaller.

The genitalia are very similar in the two species, but the duct of the spermatheca is much longer than that of *L. mimetica*.

Type-specimen.—M $\frac{12481}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

We are indebted to Dr. Sunder Lal Hora for the following note on the habitat of the species:

"Living specimens were found in the backwater of the Thumarkur nullah close to the railway bridge about three miles from Sorupeta on the Amingaon side, Assam. They were found on rotten twigs of trees which were floating in water or partly embedded in mud at the bottom. There was no vegetation except long grass near the shore. The water was quite clear and the bottom muddy."

Form **latior** nov.

The shell of this form, which is closely allied to the typical *L. horae* differs in its thicker shell, broader body-whorl, shorter spire, and in the fact that it possesses slight traces of a columellar callus.

Dr. Hora obtained two specimens from near Amingaon in Assam and has furnished us with the following note on the habitat :

"Living specimens were found attached to weeds in Jaulah lake situated at a short distance from Amingaon. The lake is flooded every year by the Brahmaputra. It is almost choked to the surface with water weeds, and approaches to it from all sides are through a marshy land covered with long elephant-grass. In most respects it is like the Loktak Lake in Manipur."

Limnaea acuminata Lamarck.

We have already referred to the extreme variability of this species in certain circumstances and the question has been discussed by Annandale and Prashad elsewhere (*Rec. Ind. Mus.*, XXII, p. 568, 1921). Before attempting to differentiate the species from others or to separate its various forms we must say a little more on this point. In certain places there is extreme variability and a series of shells can be selected that includes representatives of the greater number of the forms here recognized. In other places, however, the species is much more stable and its shell-characters are, comparatively speaking, constant. We do not know why this is so. So far as our experience goes, the variability seems to be rather an inherent character of certain strains or family groups in the species than to be directly due to the effect of environment. Nevill probably had the same idea, for he gave the manuscript name "var. *variabilis*" to a large series of shells from Moradabad which exhibited this character in a superlative degree.

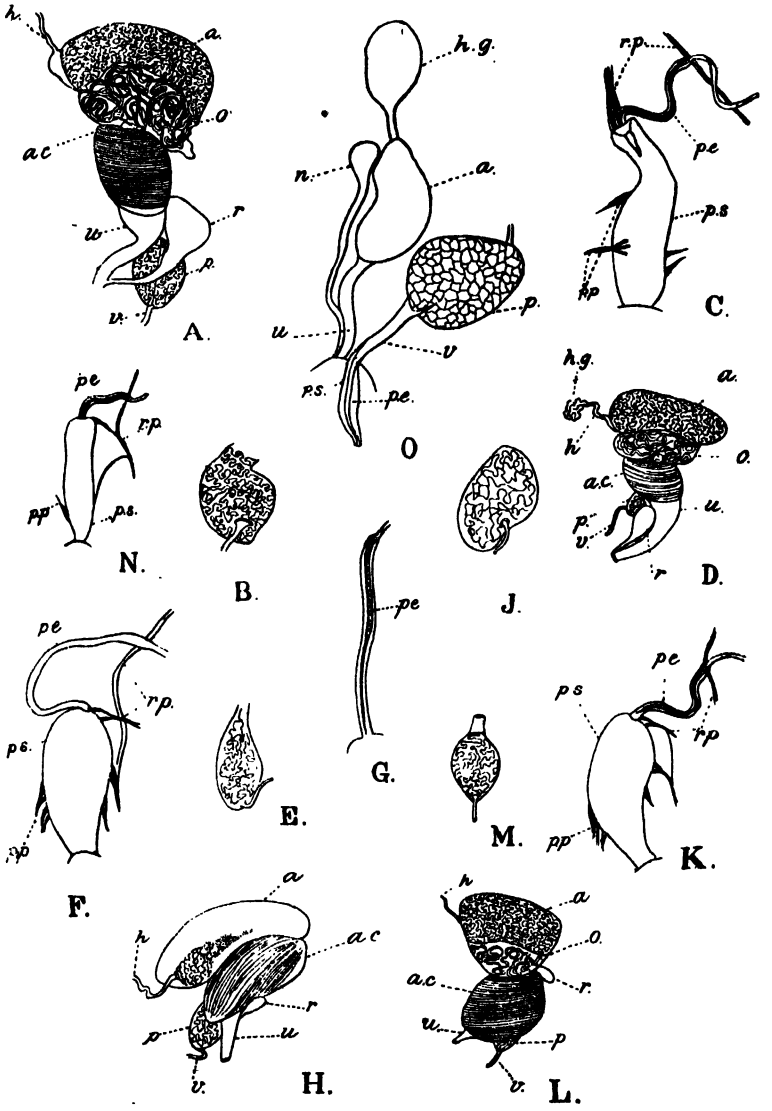
Apart from variability in the strict sense of the term true plasticity also apparently occurs. In certain places all the shells are very small. These places are either situated at rather high altitudes or else afford an environment in which succulent aquatic vegetation is scanty. Dwarfing is probably due, therefore, either to too cold a temperature or to scanty food supply and may thus be regarded as a manifestation of the phenomenon of plasticity. One other character also occurs to be definitely correlated with environment, viz., extreme thinness and pale colouration of shell, with which is associated a distinct malleation of the surface. Shells with these characters occur as a rule in running water amongst green filamentous algae.

These are the only characters, however, that we can claim definitely as due to plasticity, though we may suspect that others are also present, and for the causation of the majority of our "forms" we can make no constructive suggestion. We must, therefore, leave them as mere forms, including under the term both extreme examples of variability (e.g., f. *gracilior*) and authenticated examples of plasticity, as, for example, the mountain phase *hians*.

Geographical factors seem to have little, if any, significance in this species, but it is always rare in districts in which the differences between the dry and the wet seasons are extreme, probably because it lives, as a rule, in perennial pools and feeds mainly on succulent vegetation.

Although as a matter of convenience we treat these forms as distinct, we must make it quite clear that all of them grade into other forms and that we have found many shells which we cannot assign definitely to any one rather than another.

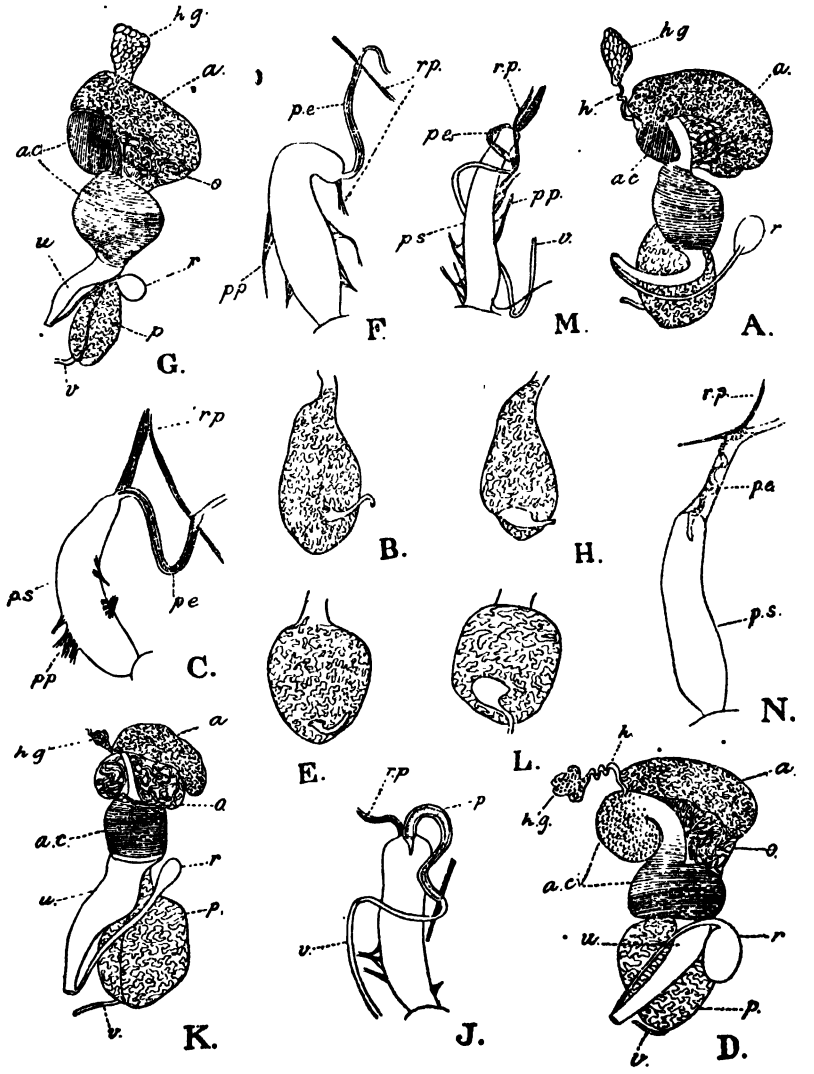
The ultimate characters whereby the shell of *L. acuminata* can be distinguished from those of allied species are of a very subtle kind. We must rule out colour, size, thickness and even sculpture completely, as all of these are liable to extreme variation, and even outlines must be



GENITALIA OF LIMNAEIDAE.

A-C. *Limnaea laticallosa.*
D-G. *L. peregra.*
H-K. *L. persica.*
L-N. *L. truncatula.*
O-*L. horae.*
B, E, J, M. Ventral view of prostate gland.
Lettering as in page 157.

considered with the greatest caution. Practically all that remains as a sure foundation for specific diagnosis is the nature of the spiral course of the shell, the form of the outer lip and a number of negative characters which differentiates the species from certain others but not from its nearest allies. We may deal with the last first. The whorls and their upper extremity is never flattened or truncate. The suture is



GENITALIA OF LIMNAEIDAE.

A C. *Limnaea auricularia*.
D-F. *L. andersoniana*.
G-J. *L. acuminata*.
K-N. *L. lutcola* f. *ovalis*.

B, E, H, L. Ventral view of prostate gland.
Lettering as in page 157.

never anything but linear. The body-whorl is never greatly inflated and the spire is rarely very short. The apex is never blunt. The sculpture is never very prominent, but the shell is never quite smooth. The mouth of the shell is never very oblique and always relatively high and narrow. So far as positive characters are concerned, the outer lip differs from that of the nearest ally of the species (*L. yunnanensis*) in that it is very little convex as a whole in lateral view in a ventral direction. The lower part, however, may project a little in this direction. From other allied forms the structure of the spire differs considerably. The suture is very oblique and roughly gyrate and the whorls are, as it were, very lightly wound together. The slope towards the apex is therefore gradual and even and the spire passes into the body-whorl gradually and without an abrupt step. The length of suture, moreover, seen in dorsal view just above the body-whorl, is always considerably longer than the diameter of the base of the spire taken with the callipers at right angles to the main axis of the shell. In the great majority of shells there is a perceptible change in the direction of the suture, which turns upwards slightly on the outer part of its final gyration. The direct length of the spire is usually greater than the direct basal diameter.

The jaws and radulae closely resemble those of the European *L. peregra*, but the mandible is stouter and the teeth a little shorter and broader in proportion. The mandible is stout and as a rule almost semicircular. Occasionally, however, it is subquadrate, the lateral extremities being obliquely truncate. The posterior margin is sinuate or nearly straight. The lateral pieces are short, tapering, slender and strongly curved.

The radular formula is variable, but there are usually about 20 marginals. The teeth are short and stout. The central is relatively large and its cusp is markedly asymmetrical. The laterals are normally tricuspid with the mesocone large and with slightly sinuate and distinctly lanceolate outline. The entocone is situated considerably in front of the ectocone, which is rather small. All but the outer marginals have the free margin transverse with a large outer tooth and one or two outer denticulations near the base.

We have not found any constant difference in the jaws and radulae of the different species.

The genitalia conform to the type of the group. The penis-sheath seems to be longer and narrower than in *L. peregra* and the penis probably shorter. The duct of the spermatheca is also longer.

The range of this species is somewhat restricted by the fact that it always lives in bodies of water which are permanent throughout the year and contain abundant vegetation. It rarely leaves the water, but is occasionally found on the upper surface of water lilies and similar plants. It feeds chiefly on soft vegetation and is particularly fond of the decaying leaves of *Limnanthemum* and water lilies. On occasion it is cannibalistic and in captivity will feed on soaked bread.

Forma **typica**.

1837. *Limnaeus amygdalum*, Troschel in Wiegmann's *Archiv. fur. Naturg.*, III, p. 168.

1841. *Lymnea acuminata*, Delessert, *Recueil Coquilles decrit par Lamarck*, pl. 30, figs. 6-A and B.

1873. *Limnaea acuminata*, Sowerby in Reeve's *Con. Icon.*, Sp. 66, pl. x.

1876. *Limnaea acuminata*, Hanley & Theobald, *op. cit.*, p. 30, pl. lxix, figs. 8, 9.
1878. *Limnaeus acuminatus*, Nevill, *op. cit.*, p. 233.
1881. *Limnaea acumiqata* var. *amygdalum*, Martens, *Conch. Mittheil.*, I, p. 76, pl. xiv, figs. 7, 8.
1921. *Limnaea acuminata*, Annandale & Prashad, *op. cit.*, p. 568, fig. 12a, b.

In this form the shell is always fairly large and has a regularly ovate outline. The spire is short and broad. The colour of the shell is variable and the sculpture consists of fine curved vertical lines without spiral lines or ridges or with sculpture of the kind very feebly developed.

We have examined specimens from the Punjab, United Provinces, Central Provinces, Chota Nagpur, Bengal and Assam.

Form **patula** Troschel.

1837. *Limnaeus patulus* Troschel, *op. cit.*, p. 167.
1881. *Limnaea acuminata* var *patula*, Martens, *op. cit.*, p. 75, pl. xix, figs. 1, 2.
1919. *Limnaea acuminata*, Annandale & Prashad, *Rec. Ind. Mus.*, XVI, p. 140, pl. v, fig. 1.

This is a considerably narrower form of equal or greater size with a relatively much larger spire. The mouth of the shell is less expanded, especially towards the anterior extremity.

We have examined specimens from Peshawar, the Kangra valley, Rawalpindi, the Salt Range in the Punjab, Chota Nagpur, the Nepal valley in the Himalayas, Mysore, Hyderabad (Deccan), the Kurnool district of Madras, and Manipur in Assam.

Form **chlamys** Benson.

1836. *Limnaea chlamys*, Benson, *Journ. As. Soc Bengal*, V, p. 744.
1876. *Limnaea chlamys*, Hanley & Theobald, *op. cit.*, p. 30, pl. 69, figs. 5, 6.
1919. *Limnaea chlamys*, Annandale & Prashad, *Rec. Ind. Mus.*, XVI, pp. 142—143, fig. 4; pl. v, fig. 3.

This form is intermediate between f. *typica* and f. *patula*. The spire is, however, narrower than in either and the columella a little more twisted.

We have examined specimens from the Gurdaspur district of the Punjab, from Moradabad in the United Provinces, from the Dehing river in the extreme east of the Himalayas, and from Manipur in Assam.

Form **rufescens** Gray.

1820. *Limnaea rufescens*, Gray in Sowerby's *Genera of Shells*, I, Limnea, fig. 2.
1873. *Limnaea patula*, Sowerby in Reeve, *op. cit.*, pl. 2, Sp 10.
1876 *Limnaea rufescens*, Hanley & Theobald, *op. cit.*, p 30, pl. 69, figs 1—4.

This is a still narrower form than any other with which we have dealt and has a larger spire. The mouth of the shell is also relatively shorter and less expanded. The colour of the shell is not always redder than that of other forms.

We have examined specimens from Peshawar and Sind, Ghazipur in the United Provinces, Chota Nagpur, Bengal, Burma, the Andaman Islands, Colair Lake in the Kistna district of Madras, and Secunderabad.

Form **gracilior** Martens.

1873. *Limnaea rufescens*, Sowerby in Reeve, *op. cit.*, pl. 3, Sp. 14.
1876. *Limnaea rufescens*, var. Hanley & Theobald, *op. cit.*, p. 30, pl. 70, fig. i.
1881. *Limnaea acuminata* var. *gracilior*, Martens, *op. cit.*, p. 77.
1921. *Limnaea acuminata*, Annandale & Prashad, *op. cit.*, p. 569, fig. 12 g. h.

The extreme limit of narrowness of the shell in *L. acuminata* relative to size is reached in the form *gracilior*. The spire is relatively long and narrower than that of f. *rufescens*. The mouth of the shell is, as a rule, still less expanded than that of the latter form. The sculpture is often inconspicuous, and the surface of the shell has a smooth appearance. The colour of the shell varies from a dull gray or cream to a light pink.

We have examined specimens from Calcutta and Raneegunge in Bengal, from the districts of Singbhum and Manbhum in Bihar and Orissa, the Ganjam district of Madras, Ghazipur and Moradabad in the United Provinces, and from Moulmein, Mandalay and the Northern Shan States in Burma.

Form **hians** Sowerby.

1873. *Limnaea hians*, Sowerby in Reeve, *op. cit.*, Sp 57, pl. ix.
1886. *Limnaea hians*, Clessin, Martini & Chemnitz's *Conch. Cab. Limnaeeea*, I, p. 392, pl. lv, fig. 9.
1915. *Limnaea* (*Gulnaria*) *hians*, Preston, *op. cit.*, p. 113.

This is the smallest of forms known to us in the species. It appears to be a curious dwarfed phase adapted to life in lakes and pools at high altitudes. In general form the shell approaches that of f. *patula*, but the mouth of the shell is, as a rule, never expanded. The spire is relatively high and narrow. The texture of the shell is somewhat variable, but the sculpture usually consists of very fine lines which become obsolete in some shells. A fine muddy deposit is often found on the outer surface of the shell while its inner surface is polished and sometimes tinted black or brown.

We have examined specimens from the Kangra valley, Sialkot in the Punjab, Bhimtal in Kumaon, Dheri Jaba in the Salt Range, Buldana in Berar, Secunderabad and in the lakes of the Nilgiri district in South India.

Form **malleata** nov.

As its name signifies the peculiarity of this form is in the texture of the shell, particularly in the region of the body-whorl. In shape the shell of this form approaches that of *patula* and is usually of small size. The body-whorl, except the outer lip, is marked by well-defined malleations in which the entire thickness of the shell takes part.

We have examined specimens from Peshawar, Wazirabad and Madhopur in the Punjab, and Manipur in Assam.

Form **brevissima** nov.

This form is closely related to the typical *L. acuminata* but differs in the spire being still further reduced with less than three whorls in the spire. This feature is apparently an abnormality.

We have examined specimens from Nagpur.

Limnaea biacuminata sp. nov.

The shell of this species resembles that of *L. acuminata* f. *hians* in some respects, but is easily distinguished by its being strongly spindle-shaped, the anterior margin of the shell being pointed as well as the apex of the spire. The shell thus tapers towards both extremities. Its bilateral asymmetry is very great, the middle region of the outer lip projecting considerably in a wide arc. Apart from the convexity thus produced the shell is narrow and elongate. The mouth is very large, ovate, almost symmetrical bilaterally, and in ventral view projects forwards much beyond the body-whorl. The columella is slightly twisted and has a broad fold, which extends forwards only to a point a little more than half way along the major axis of the mouth. It is joined to the upper lip above by a well-developed callus. The umbilicus is completely occluded. The shell is thin and fragile. The sculpture consists of fairly strong curved longitudinal striae which are situated rather far apart and have a regular symmetrical character. The colour is very pale luteous.

The jaw and radula closely resemble those of *L. acuminata*, but the posterior margin of the mandible is nearly straight, only slightly convex and not at all sinuate.

Type-specimen.—M. $\frac{12466}{2}$ Zool. Surv. Ind. (*Ind. Mus.*).

We have examined specimens from the Hosainsagar tank between Secunderabad and Hyderabad and from Naini Tal, Kumaon.

The species seems to be a lacustrine form. We keep it specifically distinct from *L. acuminata* with some doubt, but the shape of the mouth of the shell seems to be both constant and characteristic.

Limnaea luteola Lamarck.

1925. *Limnaea luteola*, Annandale & Rao, *op. cit.*, p. 106.

The characters by which the shell of *L. luteola* is distinguished from those of related species are rather less elusive than in *L. acuminata*, but the chief feature in the shell which distinguishes it from that of *L. acuminata* lies in the structure of the spire and the form of the body-whorl. The negative characters in specific diagnosis enumerated under *L. acuminata* are applicable to *L. luteola* also.

The spire is as a rule about $\frac{1}{3}$ as high as the shell and consists of four or five gradually increasing transverse whorls which are never very convex. The suture which is always more or less transverse, and the length of which is never less than the height of the spire affords the chief character of distinction between the two species. The mouth of the shell is usually narrow ovate, evenly rounded anteriorly, and gradually narrowing towards its posterior extremity. The outer lip is never so expanded or so convex in outline as that of *L. acuminata*. The columellar callus is thin and broad, while its twist is short and less conspicuous. The texture and sculpture of the shell are variable in the different forms of the species.

The jaw and radula have the same characters as those of *L. acuminata*, the former being a little more variable than the latter.

In the genitalia the prostate differs from that of *L. acuminata* in being more or less regularly quadrate in outline.

This species is much less particular in its choice of a habitat than *L. acuminata* and is frequently found in bodies of water which dry up periodically. When this occurs it buries itself in the mud. It seems to obtain the greater part, if not the whole, of its nourishment from vegetable matter in mud and they may often be seen even in hot sunshine outside the water, as a rule on the mud. It is noteworthy that there should be so little difference between the radula and jaw of species so different in habits as *L. luteola* and *L. acuminata*.

Forma **typica**.

1841. *Limnaea luteola*, Delessert, *op. cit.*, pl. 30, figs. 5-A and B.
1881. *Limnaea tigrina*, Martens, *op. cit.*, p. 85, pl. xv, fig. 5.

In this form the shell is of fairly large to very large size. The body-whorl has a somewhat compressed form and the outer lip, the edge of which is often introverted above, is nearly straight for the greater part of its length. The spire is broad and short. It tapers gradually and its suture is more oblique than in some forms. The shell is, as a rule, rather thick and almost smooth. Pale vertical stripes are sometimes present.

This form has a much wider distribution in the Indian Empire than the typical *L. acuminata*. We have examined specimens from Rawalpindi, Srinagar in Kashmir, the Punjab Salt Range, Kulu, Delhi, Naini Tal, Mussoorie, Pharping in Nepal, from Calcutta, Rajmahal and Raneegunge in Bengal, from Manipur in Assam, from Ranchi and Manbhoom in the Province of Bihar and Orissa, from Rangoon and the Andaman Islands, from Kallikote (Ganjām district), Kurnool, Secunderabad, Golconda, Madras, Travancore, Mysore, Kallar (Nilgiri district) in South India, from Salsette in Goa, and from Nagpur, Itarsi and Pachmarhi in the Central Provinces.

Form **ovalis** Gray.

1820. *Limnaea ovalis* Gray in Sowerby, *op. cit.*, *Limnaea*, fig. 4.
1876. *Limnaea ovalis*, Hanley & Theobald, *op. cit.*, p. 30, pl. lxx, figs. 2, 3.
1881. *Limnaea nucleus*, Martens, *op. cit.*, p. 82, pl. xv, figs. 8, 9.

Although the extreme form is very different from the form *typica* the two intergrade to such an extent that it is often difficult to decide in individual shells to which they should be assigned. The form *ovalis* is always large and stout with the body-whorl typically much more inflated than in the forma *typica* and with the outer lip curved. The spire is smaller and more acuminate and tapers more abruptly. The suture is much more transverse.

We have examined specimens from the Kangra valley, from Almora and Bareilly in the United Provinces, from Purneah in Bihar and Orissa, from Calcutta, Barrackpore, Rajshahi and Raneegunge in Bengal, from Manipur in Assam, from the Southern Shan States and the Andamans, from Rambha, Madras, Nellore, Pondicherry and Mysore in South India, and from Kamptee in the Central Provinces.

Form **australis** nov.

1876. *Limnaea pinguis* Hanley & Theobald, *op cit.*, p. 30, pl. lxx, figs. 7—10.
1915. *Limnaea (Gulnaria) pinguis*, Preston, *op. cit.*, p. 113.

This is a small form resembling the f. *typica* but with much narrower and a more elongate spire, with the suture more impressed and more sinuous and without any compression of the body whorl. The shell is also thinner and as a rule more polished.

We have examined specimens from Rasalpore, Dharamsala, Ferozepore in the North-west of India, from Roorkee, Mirzapore and Moradabad in the United Provinces, from Puri, Ranchi, Chakradharpur and Chandbally in Bihar and Orissa, from Calcutta, Garia, and Chittagong in Bengal, from Gauhati in Assam, from Rambha, Kaligiri (Nellore district Madras, Hosainsagar and Golconda (Hyderabad State), Trichinopoly, Travancore, Bangalore, Coimbatore, and the Nilgiri district in South India, from Satara and Karachi in Bombay, from Nagpur and Buldana in the Central Provinces, and from Ceylon.

Form **impura** Troschel.

1881. *Limnaea succinea* var. *impura*, Martens, *op. cit.*, p. 86, pl. xv, figs. 6, 7.
1919. *Limnaea acuminata* var. *nana*, Annandale & Prashad, *Rec. Ind. Mus.*, XVI, pp 141–142, fig. 3 ; pl. iv, fig. 1 ; pl. v, fig. 2.

This is a still smaller form with rather narrower body-whorl, pyriform mouth and a thicker shell. The surface of the shell is feebly smooth and rather rough. It is usually covered with a black deposit. The colour is always pale.

We have examined specimens from Naukuchia in Kumaon, Dimapore in Assam, Kallikote, Rambha and Barkuda in the Ganjām district, from Secunderabad, from the Malabar district, from Khandalla in Bombay, and from Rangoon.

Form **succinea** Deshayes.

1834. *Limnaea succinea* Deshayes, *Voy. dans. Ind. Belanger. Zool*, p. 418, pl. ii, figs. 13, 14.
1862. *Limnaeus succineus*, Kuster, *op cit*, p. 29, pl v, figs. 18, 19.
1919. *Limnaea pinguis*, Annandale & Prashad, *op. cit.*, p. 144, fig. 5, pl. v, fig. 4.

This is a rather large very narrow form with a large tapering spire and a comparatively small mouth. The outer lip is arched. The shell is pale and thin. Its most characteristic feature is its sculpture, which includes very fine spiral striae as well as interrupted longitudinal striae. These give it a silky lustre, which doubtless suggested its name.

We have examined specimens from Kashmir and Benares in Upper India, and from Hosainsagar, Bolarum (Hyderabad State), Gōdāvari, Kurnool, the Nilgiris and the Palni Hills in South India.

Form **siamensis** Sowerby.

1873. *Limnaea siamensis*, Sowerby in Reeve, *op, cit.*, Sp. 63, pl. x.
1915. *Limnea (Gulnaria) siamensis*, Preston, *op. cit.*, p. 113.
1925. *Limnaea luteola* race *siamensis* Annandale & Rao, *op. cit.*, p. 107.

This form seems to be almost in the nature of a local race representing the eastern type of the species, The shell is never large. It is

easily distinguished by its narrow, ovate, almost symmetrical outline and by its relatively long auriculate mouth. The suture is not so impressed as in most forms of the species and the spire is relatively small. The texture of the shell varies considerably. In some localities it is very thin with the columellar callus poorly developed.

We have examined specimens from He-Ho and the Inlè Lake in the Southern Shan States and from Rangoon.

Limnaea ovalior Annandale and Prashad.

1921. *Limnaea ovalior*, Annandale & Prashad, *op. cit.*, pp. 572–573, fig. 13 A, pl. vii, figs. 4–6.

The shell of this species, in spite of its resemblance to that of *L. luteola* f. *ovalis* in form, is easily distinguished from the latter by the size and form of the spire, by the structure of the columellar callus, and by the sculpture and colour.

The very regular and symmetrically ovate shape of the shell, the relatively short, blunt spire with its base nearly as broad as the upper part of the body-whorl, its height being only ¼ of that of the shell, the absence of angulation in the whorls of the spire, the broad and coarse columellar callus which extends very little below the body-whorl in ventral view, the peculiar sculpture and opaqueness of the shell are the chief distinguishing features of the species.

The jaw and radula are not unlike those of *L. luteola* f. *ovalis*.

In the genitalia the duct of the spermatheca in specimens examined is much shorter than that of the form *ovalis*.

The species is apparently confined to parts of Assam. We have examined specimens from Dimapore and the Manipur valley.

The members of the species lead an almost amphibious existence in and on damp mud at the edge of small pools which are devoid of true aquatic vegetation, or in very foul water of jungle-pools. They appear to feed on mud and decaying vegetable matter.

Key to the living Species of limnaea known from the Indian Empire and its Immediate frontiers.

1. Shell very small and delicate (less than 10 mm. high), narrow with the apex blunt.
   A. Spire with 2 whorls ; columellar callus present ... *L. mimetica*
   B. Spire with 2½ whorls ; columellar callus absent ... *L. horae.*
2. Shell never so delicate and usually more than 10 mm. high.
   A. Spire scalariform or at least canalized at the base. Columellar fold not narrowed immediately below the umbilicus.
      I. Spire at least moderately exserted ; body-whorl not greatly expanded ... ... *L. lagotis.*
      II. Spire extremely short ; body-whorl greatly inflated ... ... *L. bervicauda.*
   B. Spire never scalariform (except as an abnormality) or canalized at the base. Columellar fold varying in structure.
      I. Spire with 5 complete whorls.
         (*a*) Shell less than 20 mm. high, with the body-whorl not expanding outwards and the columellar callus exceptionally broad and coarse ; the spire moderate ... ... *L. laticallosa.*

(*b*) Shell usually much more than 20 mm. high with the body-whorl expanding outwards and the columellar callus well but not exceptionally well developed; the spire exceptionally long and slender ... ... *L. stagnalis.*

II. Spire with not more than 4 complete whorls.

(*a*) Shell with the columellar callus exceptionally well developed.

(i) Whorls of spire increasing gradually in size; the basal whorl of the spire not twice as broad as the one above it.

L. Body-whorl much longer than spire in dorsal view ... .. *L. andersoniana.*

B. Body-whorl and spire subequal in dorsal view ... . *L. truncatula.*

(ii) Basal whorl of spire more than twice as broad as the whorl above it.

L. Suture impressed; umbilicus broadly rimate ... ... *L. bowelli.*

B. Suture not impressed; umbilicus narrowly rimate ... ... *L. hookeri.*

(*b*) Columellar callus not exceptionally well developed.

(i) Spire very short, at least 3 times as broad at the base as high.

α Spire passing evenly into the body-whorl; shell almost bilaterally symmetrical in dorsal view ... ... *L. oralior.*

β. Spire very much narrower than upper margin of body-whorl, shell very asymmetrical bilaterally.

A. Columellar fold narrowed abruptly below umbilicus ... ... *L. auricularia.*

B. Columellar fold poorly developed, not narrowed below umbilicus ... ... *L. physcus.*

(ii) Spire longer, much less than 3 times as broad at the base as high.

L. Shell small (less than 15 mm. high), with the mouth not at all dilated; (upper margins of whorls convex) ... ... *L. hordeum.*

B. Shell more than 15 mm. high with the mouth more or less dilated.

A. Length of suture seen in dorsal view at base of spire considerably greater than height of spire.

1. Height of mouth of shell at least $\frac{3}{4}$ of the total height... ... . *L. persica.*

2. Height of mouth of shell less than $\frac{3}{4}$ of the total height .. .. *L. shanensis.*

B. Length of suture at base of spire not or hardly longer than height of spire.

1. Diameter of base of spire measured at right angles to main axis of shell considerably less than height of spire.

(*a*) Anterior margin of mouth of shell broadly rounded or subtruncate *L. acuminata.*

(*b*) Anterior margin of mouth of shell pointed .. .. *L. biacuminata.*

2. Diameter of base of spire not or hardly less than height of spire.

(*a*) Outer lip of shell slightly dilated ... *L. luteola.*

(*b*) Outer lip more dilated, at any rate below.

I. Arc of lip quite regular; apex of shell sharply pointed ... ... *L. iranica.*

II. Arc of lip irregular; apex bluntly pointed ... ... *L. gedrosiana.*

Table of measurements in millimeters.

Name of species.	Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.	Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.	Height of shell.	Height of aperture.	Maximum breadth of shell.	Maximum breadth of aperture.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Limnaea stagnalis	47·7	27·0	23·7	15·3	45·1	26·9	24·3	14·8	40·2	25·5	24·5	18·0
L. stagnalis form *kashmiriensis* ..	54·0	28·0	28·0	19·4	52·0	33·0	27·0	19·0	48·0	28·0	25·0	17·0
L. do f. *minor*	34·0	21·0	18·2	12·0	32·0	18·5	16·2	10·4	30 0	17·0	16·0	11·2
L. persica	13·3	11·1	10 0	7·0	14·4	12 4	11·0	8·9	8 8	7·2	6·3	4·5
L. lagotis f. *striata*	17·0	13·9	13·8	9·1	19·2	16·7	14·8	9·7	13·0	10·0	9·8	7·1
L. do. f. *costulata*	17·5	12 8	11·7	8·0	14·5	10·7	10·2	6·3	10·5	7·4	7·1	4·5
L. do. f. *solidissima*	22·0	18·1	17·2	10·0	21·4	15·1	14·4	8·3	19·2	13·9	12·5	8 1
L. do. f. *subdisjuncta*	12·7	8·6	8·5	5·0	12·2	8·5	8·2	5 5	10·5	6·2	6·7	4·0
L do. f. *bactriana*	17·7	12·2	11·7	7·0	10·0	6·8	6 7	4·1	7·5	5·1	4·5	2·5
L. do. f. *defilippii*	17·8	11·5	10·4	5·9	17·3	12·5	10·5	6·8	14·8	10·5	9·3	6·0
L. brevicauda	17·8	14·9	14·8	10·0	14·8	12·5	12·4	8·5	15·1	11 7	11·9	7·7
L. auricularia	17·9	14·7	14·0	8·5	23 5	19·3	17 5	11·2	10·5	9·4	8·7	5·5
L. truncatula	8·8	4·2	5·0	2·0	10·6	5·4	5·6	2·5	7 8	3·4	4·4	2·0
L. andersoniana f. *typica*	7·5	5·2	4·6	2·7	7·0	4·6	4·3	2·4	6·3	4·2	3 9	2·3
L. do. f. *simulans* ...	9·0	5·5	5 7	3·2	11·2	6·7	6·7	3·7	9·8	6·0	6·2	3·4
L. do. f. *turbinicola* ...	11 5	7·5	6·3	3·5	...	...	...	...	...	...	...	.
L. do. f. *intermedia* ...	6·8	4·4	4·3	2·0	7·3	4·5	4·3	2·5	5·4	3·2	3·8	2·2
L. hookeri	8·9	6·5	5 5	3·6	8 4	6·3	5·6	3·7	11·4	7·8	7·6	4·5
L. bowelli	8 8	5·7	5·7	3·3	15·3	10·1	10 9	6·2	12·7	7 9	8·6	5·0
L. hordeum	6·1	3 7	3 4	2·0	4·8	2·6	2·4	1·4	3·6	2·1	1·9	1·0
L. laticallosa	15 7	9·7	8·4	4·9	15·2	10·1	8·8	5·3	15·0	9·2	8·0	4·7
L. iranica	18·4	14·2	11·4	8·0	15·4	11·9	9·5	6·5	14·2	10·7	8·3	5·5

L. gedrosiana	11·5	9·0	7·1	5·0	9·3	7·1	6·0	4·2	8·4	6·4	4·8	3·3
L. do. f. *rectilabrum*	10·8	7·4	6·4	3·8	15·4	11·7	10·8	7·5	14·8	10·8	9·0	6·5
L. shanensis	11·8	7·9	7·6	5·3	9·9	6·9	6·2	4·0	9·4	6·5	5·0	3·5
L. do. f. *superstes*	10·1	7·5	5·4	4·2	7·6	5·1	4·2	2·8	...	...	...	...
L. do f. *hehoensis*	7·3	5·4	4·6	2·9	6·6	5·3	3·9	3·0	6·1	5·0	3·7	2·8
L. physcus	8·4	7·2	6·5	4·2	9·1	8·0	6·0	3·7	...	...	...	...
L. mimetica	7·0	5·1	3·5	2·8	5·6	4·5	2·9	2·3	4·9	3·7	2·5	2·0
L. horae	6·0	4·3	3·0	2·4	5·4	3·6	2·9	2·0	...	..	...	...
L do. f. *latior*	4·9	3·7	3·0	2·0	...	...	...	...	...	...	...	...
Limnaea acuminata f. *typica* ...	38·2	29·9	22·4	14·7	25·6	20·5	16·6	11·0	18·6	15·5	13·0	9·2
L. acuminata f. *patula*	31·8	24·0	17·9	12·5	28·7	20·9	15·5	10·3	22·7	17·0	12·9	9·0
L. do. f. *chlamys*	32·6	28·5	20·9	16·0	26·4	20·7	16·4	12·5	17·8	13·3	11·6	8·5
L. do. f. *rufescens*	38·7	29·2	19·7	14·0	37·1	27·1	18·0	13·8	24·9	17·3	11·2	7·5
L. do. f. *gracilior*	28·4	18·8	12·0	9·5	26·5	17·6	11·5	8·0	24·6	16·8	9·6	7·2
L. do. f. *hians*	13·3	9·6	7·4	5·0	11·7	8·1	6·3	4·2	11·3	8·0	5·5	3·7
L. do. f. *malleata*	17·4	13·0	9·4	6·8	19·4	15·0	11·0	8·2	18·3	13·7	11·3	8·0
L. do. f. *brevissima*	16·9	14·2	11·1	8·2	17·0	13·8	11·0	7·5	...	...	...	...
L. biacuminata	18·2	14·2	10·1	7·6	15·0	11·0	7·8	5·7	13·9	10·6	7·3	5·5
L. luteola f. *typica*	28·5	20·3	16·8	10·3	24·4	16·1	13·0	9·2	18·1	13·8	11·3	6·8
L. do. f. *ovalis*	20·0	15·2	13·6	8·0	18·7	12·7	11·6	6·5	12·8	9·4	8·6	5·0
L. do. f. *australis*	20·0	13·0	11·9	7·0	12·0	9·0	7·7	5·0	11·2	7·7	7·0	4·4
L. do. f. *impura*	19·3	13·5	10·9	7·3	14·8	11·0	10·2	6·5	8·8	6·1	5·3	3·5
L. do. f. *succinea*	21·3	13·8	11·0	7·0	19·9	15·4	12·8	8·4	16·3	11·6	9·5	6·6
L. do. f. *siamensis*	16·4	11·0	9·5	6·1	15·1	11·1	9·7	6·5	10·5	7·7	6·6	4·5
L. ovalior	17·9	13·9	12·4	7·8	17·6	12·5	11·8	7·0	13·9	10·8	9·7	6·0

NOTE ON A BRACKISH-WATER ACTINIAN FROM MADRAS

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Our knowledge of the brackish-water Actinians in India dates from the time of Stoliczka[1] who, in the year 1869, recorded a form from Port Canning in Lower Bengal. He described the anatomy and habits of this form under the name *Sagartia schilleriana* Stoliczka. In 1907 Annandale[2], while studying the fauna of the brackish-water ponds in the same locality, discovered three forms of which one was Stoliczka's species which he ascribed to the genus *Metridium*. He regarded the second form as a variety of *Metridium schilleriana* and the third as the young of the variety. In 1914 he recorded the two latter from the Chilka Lake, and regarded them as the types of his genera *Pelocoetes* and *Phytocoetes*, respectively.[3] The Gangetic and Chilka species of the former were identical, while those of the latter were distinct. *Metridium schilleriana* was, however, not found in the Chilka Lake. Considerable light has been thrown on the structure and bionomics of the Indian brackish-water Actiniaria by the researches of the late Dr. Annandale, but the field is yet wide and requires thorough investigation. In a recent paper on the classification of Actiniaria Stephenson[4] has discussed the mutual relationship of the Indian brackish-water Actinians in great detail. He suggested the new name *Diadumene* for the genus containing Stoliczka's species, giving reasons for dropping the generic names *Sagartia* and *Metridium*. He regarded the Chilka species of *Phytocoetes* as the type of a distinct genus named by him *Mena*, and grouped all the known Indian brackish-water genera under the new family name *Diadumenidae*.

There are thus four species of brackish-water Actiniaria representing the four genera *Diadumene*, *Pelocoetes*, *Phytocoetes* and *Mena*. The distribution of the species seems to be restricted, having been recorded hitherto from the Gangetic delta and the Chilka Lake. It is, however, probable as suggested by Annandale, that *Pelocoetes exul* (first recorded from Port Canning as a variety of *Diadumene schilleriana*) is more widely distributed than we know. It occurs in smaller numbers in the brackish-water area at Madras. I have been able to find only two individuals of this species in a collection consisting of several individuals of the form which is the subject of the present note. One of them was abnormal, having only 11 divisions of the oral disc, 11 pedunculated and 11 simple tentacles in two cycles. The mesenteries were, however, normal.

The form described in this note is apparently new to science[5] and is probably closely allied to *Pelocoetes*. It is not intended here to

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[1] Stoliczka, F., *Journ. As. Soc. Bengal*, XXXVIII, p. 28, pls. X-XI (1869).
[2] Annandale, N., *Rec. Ind Mus.*, I, p 47, pls iii-iv (1907).
[3] Annandale, N., *Mem. Ind. Mus.*, V., pp. 72-88 (1915).
[4] Stephenson, T.A., *Quart. Journ., Micros Sci*, LXIV, pp. 520—523 (1920).
[5] Specimens of this form collected by Dr. F H. Gravely and myself in January 1922 have been sent to Mr. T.A. Stephenson for identification.

discuss the systematic position of this new Actinian on inadequate anatomical data, but simply to record a few observations made in the

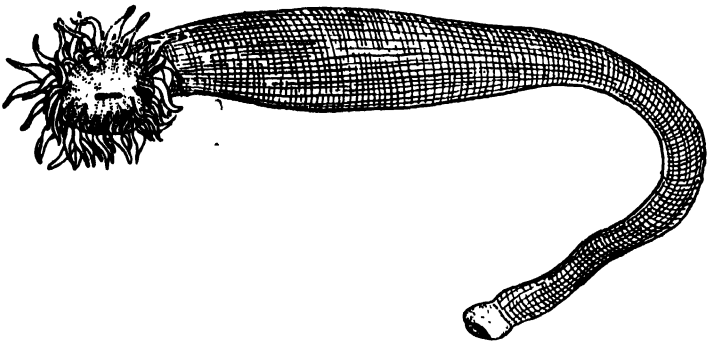


FIG. 1.—Brackish-water Actinian from Adyar, Madras.

field and in the laboratory, which may interest workers on the subject.

In the year 1917, while collecting worms and molluscs on the edge of a brackish-water area near Adyar in Madras, my attention was arrested by the presence of a number of Actinians in burrows at the bottom of shallow pools of water. They had long and thin, fully expanded tentacles of a creamy white colour and were found buried up to the edge of the oral disc. At first sight they appeared to be sticking on to the muddy bottom by their basal disc. On attempting to remove one of the Actinians from its supposed attachment to the mud, it suddenly withdrew into the burrow with the tentacles grouped in a mass, and receded deeper into the burrow on inserting a small stick. Attempts to obtain the Actinians by digging the burrows resulted only in securing parts of the animals. Several complete individuals were, however, obtained with a spade which was quickly plunged into the mud close to the burrows, turning up a large lump of the soil. The animals were all picked up in a flabby condition, some of them filled with water. They had a long vermiform column with a reduced basal disc, and numerous simple tentacles arranged in cycles. In general appearance the individuals seemed to approach those of *Pelocoetes exul*, but differed in the number and arrangement of the tentacles.

Before going into some details of the anatomy and habits of the animal a short descriptive account of its habitat will not be out of place. About three miles south of Fort St. George the river Adyar opens out to the sea. On the north bank of the river lies a low area about half a square mile in extent within a few yards from the surf line. It may roughly be divided into two regions—a central zone which is deep, and a marginal zone consisting of shallow pools and channels. During heavy rains in November this division is not apparent, the whole area being covered by a continuous sheet of water. The area is in communication with the river close to its mouth and through the latter with the sea. The water at this time of the year is quite fresh. From January the level of water begins to fall and the mouth of the river is gradually closed by a sand-bank raised by the

action of breakers. For a period of about eight months in the year, commencing from March, the water is brackish and sometimes distinctly saline. The bottom consists of soft clay mixed with fine sand, and in some parts covered by vegetable debris. Large masses of algae, chiefly a species of *Enteromorpha*, float on the surface in the central zone. Isolated mangrove formations are present on the western half of the area. The fauna has a preponderating marine element, but it is probable that many of the species are distinct from the true marine ones found in the open sea. Representatives of all the marine groups except Echinodermata are present. The great masses of algae harbour a large number of animals, chief of which are Amphipods, Isopods, Turbellarians, and Nudibranchs. The marginal zone teems with life, the most striking being hermit crabs inhabiting shells of various marine Gastropods and even hollow bones, smaller Crustacea, Polychaetes and Oligochaetes. The fauna as a whole is quite varied and interesting, and an intensive survey of the area will probably yield valuable results.

The Actinians in question occur chiefly on the edge of the marginal zone east and west of the area. In the former there are fairly deep pools between artificial sand-banks, and in the latter open shallow ones. I have taken individuals from both zones, but it is easier to obtain them from the marginal zone on the west. They are conspicuous in the bright morning sun and have their tentacles fully expanded just above the burrows. As the day advances they withdraw themselves into their burrows and reappear in the evening about sunset. They are, however, much less conspicuous at sunset than at dawn. I have visited the area almost every month from July to March, but have found the Actinians only from January to March. So far as my observation goes, not a single individual was found during the other months. Their absence in this period is probably due to the heat in the first half and to the freshness of the water in the second. The fishermen of the place, who dig up the bottom for a species of polychaete worm (*Marphysa*) which they use as a bait for fish, have also remarked the absence of the Actinians during this period. They call

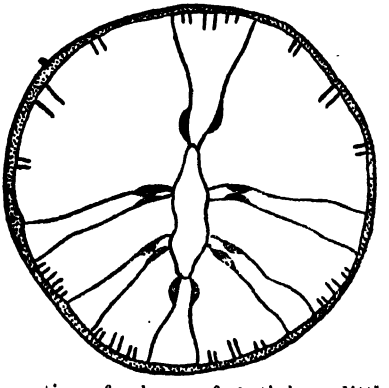


FIG. 2.—Transverse section of column of Actinian a little below oral aperture showing the arrangement of mesenteries.

them "flower-like worms" in their vernacular and are acquainted with their burrowing habits, and remarkably enough have also some notion

of their relationship to the Actinians found sticking to the cement boulders in the Madras harbour or to cables some distance from the shore.

The column of the animal closely resembles that of *Peloscetes exul* and has a reduced pedal disc at its lower extremity. The latter is a cup-shaped depression with an even margin and is filled with a sticky secretion enclosing mud and grains of sand. In incomplete individuals which are kept alive in an aquarium, a secondary pedal disc with an irregular margin is formed and functions like the real disc for sticking to the bottom. The longitudinal and transverse muscles of the column are clearly seen in the fully expanded animal, and through the thin body-wall the mesenteries and gonads are also visible. Cinclides with an elliptical outline and definite lips are present in longitudinal rows in the intermesenterial spaces. They are best seen in the fully expanded living animal, but can also be distinguished in well-preserved individuals. In the fully expanded animal the oral disc slightly extends beyond the column. It is usually lobulated, consisting of twelve radial divisions which are further subdivided in some individuals. The oval aperture is elongate and oblong and frequently tightly closed, leaving a circular opening at each end. The tentacles are usually of a cream colour, but in a few specimens they have a pinkish tinge. They are long and tapering and perforated by a minute opening at their distal extremity. They are arranged in four cycles, each consisting of 24 tentacles. The tentacles of the innermost cycle alternate with the radial divisions of the oral disc, while those of the others alternate with the tentacles of the next inner cycle. The relative lengths of the tentacles of the four cycles vary in different individuals. For instance, in some specimens the tentacles of the two inner cycles are longer than those of the outer, in others those of the two central cycles are shorter than those of the outer or the inner, while in others the tentacles of the outer cycle are much longer than those of the other three. This difference in the relative lengths of the tentacles is to be seen in both living and preserved specimens. There are six pairs of macrocnemes and eighteen pairs of microcnemes. In a few individuals there are twenty-one pairs of the latter, the three additional pairs being found between one of the pairs of directives. The arrangement of the longitudinal muscles on the primary mesenteries is identical with that of *P. exul*. The free margins of the macrocnemes bear mesenterial filaments and acontia, and next to these on the inner side the gonads. Stoma are also present on the macrocnemes. The microcnemes are all sterile. The tentacular cavities are in open communication with the intra-and inter-mesenterial spaces. Nematocysts are present on the column and tentacles, but they are more numerous on the latter. They are of two sizes, long and short ones, the former being more numerous.

Of several individuals examined, a few were immature while, all the rest bore spermaries only. Despite careful examination of a large number of specimens I have failed to find even a single specimen bearing ovaries. The ovaries are probably formed at a later quiescent period during which the animals apparently rarely come out of their burrows.

The gonads consist of a number of elliptical bodies somewhat convex above, arranged in a sinuous row between the longitudinal muscles and

the free margin of each macrocneme. They are brownish in colour with a number of orange-coloured spots and consist of polygonal cells from which the spermatozoa project, tail foremost. The latter have a roughly oval head with a moderately long tail. The narrow space between the gonads and the free margin of the macrocneme is occupied by the mesenterial filament which is divisible into two portions, the inner consisting of a row of elongate elliptical cells provided with a few long cilia, and the outer of shorter columnar cells with numerous short cilia. Nematocysts are found in large numbers in the outer portion. The two portions are intricately folded, and in the living animal perform

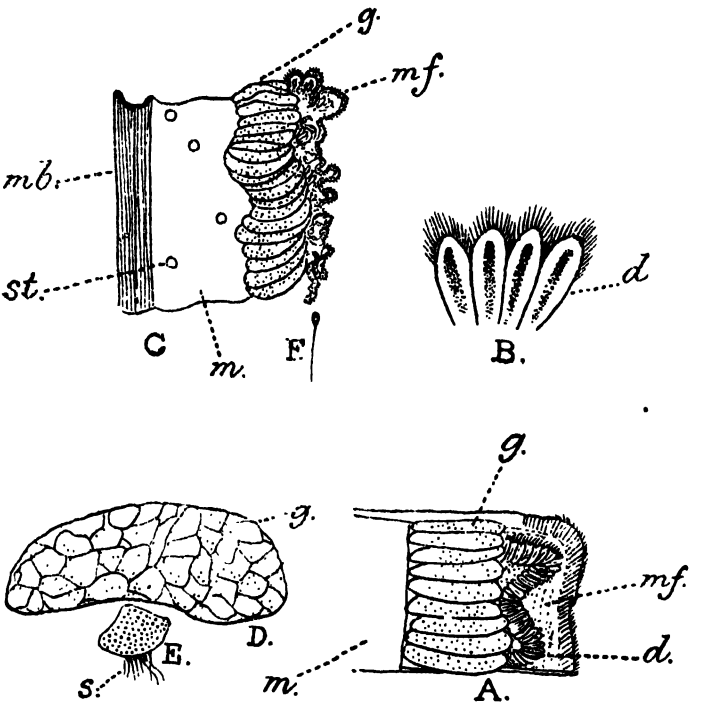


FIG. 3.- Semidiagrammatic sketch of a fertile mesentery and associated structures

A. Part of mesentery showing the disposition of gonads and filament.
B. Enlarged view of ciliated cells outside the gonads.
C. Part of mesentery from a living Actinian.
D. Portion of spermaries.
E. Single cell of spermaries with spermatozoa.
F. Single spermatozoan.

d, row of ciliated cells forming part of mesenterial filament ; *g*, spermaries ; *m*, mesentery ; *mb*, longitudinal muscle of mesentery ; *mf*, mesenterial filament ; *s*, spermatozoa, *st*, stoma.

constant wriggling movements. Remains of small Crustacea are found in abundance in the gastrovascular cavity. These apparently form the usual food of the Actinians in their natural environment. A ciliate protozoan (*Trichodina* sp.) is found in large numbers in the gastrovascular cavity and often swarming in the cavities of the tentacles. They probably find their exit through the tentacular aperture.

The following account of the habits of the Actinian is based on observations made in the laboratory of the Presidency College, Madras, in December 1918 :—

The bottom of a tall cylindrical jar was covered with soft mud obtained from the brackish-water area at Adyar to a height of about four inches. Owing to the difficulty of obtaining a regular supply of brackish-water from the area, a mixture of equal volumes of sea-water and fresh-water was used. Small burrows were made in the mud and the Actinians inserted in them up to half the length of their column. The animals under observation were sexually mature but were incomplete, measuring about four inches. They were easier to handle than the long complete individuals which could not be inserted into the burrows without injury to the column. Water in the jar was changed twice a week and the Actinians fed with plankton obtained by tow-nets from the open sea. To prevent crowding, only four individuals were kept at a time in the aquarium. Observations were only made during daytime.

On the second day the Actinians were found disengaged from their burrows and lying with their column parallel to the bottom. Three of them had their tentacles fully expanded and directed upwards, while the fourth had them slightly contracted and directed sideways. The former appeared to be shorter than on the preceding day. On examining their burrows it was found that a small portion of the column of the animals was left behind. The upper half of the column was bulged out and translucent, and the cinclides were slightly dilated. The mesenteries and gonads were visible through the thin walls of the column. All the four specimens were then irritated by a needle and it was observed that in three of them the basal half of the tentacles bent over the oral disc which gradually sank down with simultaneous jerky contractions of the upper part of the column. The tentacles were then partially enclosed by the portion of the column which had risen up as a result of the contraction. But in the fourth individual the response was different. By a sudden contraction, the upper part of the column closed over a greater length of the partially contracted tentacles and was exceedingly bulged out. After some time this individual was found floating some distance below the surface of water and in this condition it remained for several hours. On the third day, however, it had settled to the bottom and had the tentacles partially expanded.

The first set of four Actinians was replaced by a fresh one. The burrows made in the mud were filled up and the animals were left undisturbed on a level surface for three days. On the fourth day it was found that two of them had a small portion of the column buried in the mud, and the remaining two sticking to the bottom by their basal disc. All the four were then gently dislodged from their positions and laid with their column parallel to the bottom. Three days later one of them was partially buried while the others were found in a prone position. The oral disc including the tentacles was inclined towards the bottom in the former, and directed upwards in the latter. On the sixth day two individuals were found in burrows excavated, apparently, by the action of the pedal disc. It was remarkable that nearly half the length of their column was found buried. In one of them the tentacles were contracted and partially enclosed by the upper

part of the column, and in the other they were fully expanded. When gently disturbed the former withdrew itself completely in the burrow while the latter did not respond to the stimulus. The former was removed from its burrow and left in a prone position close to the burrow, and was found to have resumed its position in the burrow on the following day. The fourth specimen which remained undisturbed in the prone condition was next placed in a deep burrow up to the base of the tentacles, but was found outside the burrow on the following day.

The results of the foregoing observations may be summed up as follows :—

1. In incomplete individuals, i.e., in those of which the basal half of the column is lost in the burrow, a secondary pedal disc with an irregular outline is formed.
2. The secondary pedal disc is used primarily as a burrowing organ and secondarily as an organ of locomotion.
3. The Actinian undergoes autotomy and rapid regeneration of the lost or injured parts.
4. The tentacles and oral disc are subject to partial or more or less complete contraction.

Further observations would have yielded interesting results, but unfortunately owing to my unavoidable absence from Madras for a considerable period they could not be continued. The Actinians were, however, left undisturbed for a period of over three months unfed, and without changes of water. They were found living in an apparently healthy condition during this period. I am indebted to my teacher and friend Mr. R. Gopala Ayyar for this information. This fact points to their great powers of resistance to adverse environmental conditions.

It may be argued that my observations of the habits of the Actinians were made under conditions totally different from those in their natural surroundings and do not therefore refer to their true behaviour. In the first instance I attempted to conduct the same series of experiments in an isolated spot of the brackish-water area visiting it twice a week to record my observations, but the shallower regions of the area where the animals were found in numbers were so frequently dug up by the local fishermen for worms that my attempts to obtain correct observations in their natural surroundings had failed. I have, however, observed that the Actinians are much more sensitive to mechanical disturbances in their natural environment than under laboratory conditions. The water used for the aquarium was probably more saline than that of the area itself, and may have to some extent influenced my results. I presume, however, that the Actinians behave more or less in the same way under natural conditions as well.

I take this opportunity to express my sincere thanks to my professor Rao Bahadur K. Ramunni Menon who gave me every facility to work in the laboratory of the Presidency College.

A NOTE ON THE REPRODUCTION OF THE COMMON HYDRA OF BENGAL (*HYDRA VULGARIS*, PALLAS)

BY H. SRINIVASA RAO.

The following observations were made on *Hydra vulgaris*, Pallas, in the months of August and September 1920. The polyps were reared in cylindrical glass jars containing weeds from a pond.

Fission.—An instance of vertical fission was witnessed on the 26th August 1920. Fission was more or less complete and the two polyps were still united by the basal part of the column. One had five tentacles and the other four. The contraction and expansion of the column and tentacles of the polyps were independent. The gastro-vascular cavities were continuous and small particles were seen passing through the fluid from the gastral cavity of one into that of the other. The ectoderm and endoderm were distinct, and at the base of the polyps were observed two endodermal prominences. The ectoderm in this region was slightly depressed. (See Fig. 3.)[1]

On the following day an endodermal wall was completely formed cutting off the gastro-vascular cavity of one polyp from that of the other. The ectodermal depression was invaginated. On the third day the ectoderm of the basal disc was formed and the polyps were sticking to each other by a secretion of mucus. The same evening they were observed to have separated. The difference in the number of tentacles of the two polyps was still maintained.

Though several polyps were reared for over two months this was the only instance of vertical fission observed.

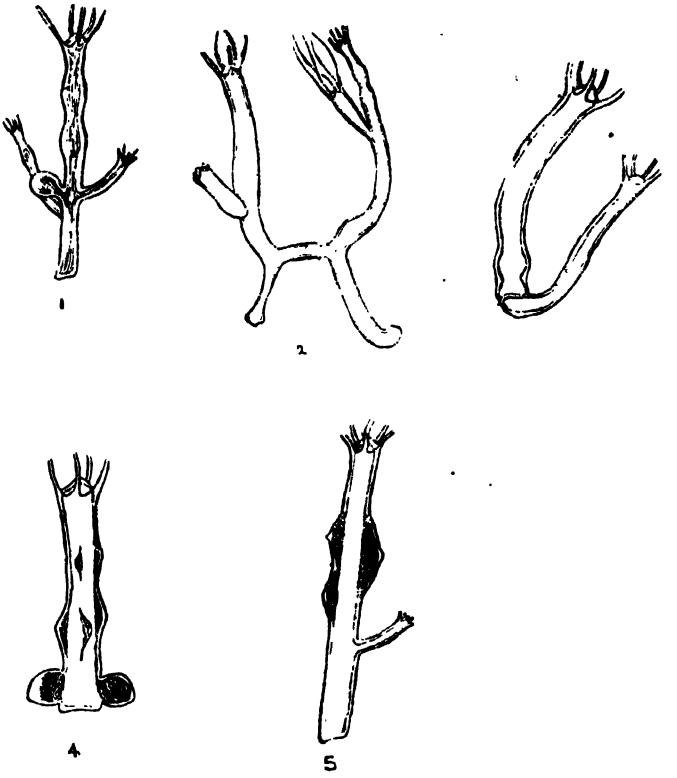
In his account of *Hydra* in the *Memoirs of the Asiatic Society of Bengal*, I, page 344, 1906, Dr. Annandale states that he has only seen three instances of vertical fission. Apparently this mode of reproduction is very rare.

Budding.—Several individuals bearing two or three buds were seen during the earlier part of August. Most of the buds were in a fairly advanced state with, as a rule, the same number of tentacles as in the parent polyp. The lower half of the column was slender and transparent, and as a result of swellings the upper half was moniliform (Fig. 1). Usually the buds were confined to a small zone about the middle of the column; and it was remarkable that the column below this zone did not present a moniliform appearance. This phenomenon was noticeable in the budding individuals only. That the swellings are different from buds is suggested by the fact that they sometimes disappear and reappear in the same place. The entire gastro-vascular cavity is clear, and any food particle too large for it can at once be seen. Several individuals with the swellings were examined, and in none of them were they the result of distension by food particles or other foreign matter.

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[1] The figures illustrating this note are reproduced, with the kind permission of the Secretary, Bombay Natural History Society, from the Society's Journal in which this paper was first published.

The budding polyps were generally found attached to the bottom and sides of the glass-jar, and to the underside of weeds.



The polyps attached to the sides lay usually inclined upside down with the tentacles fully expanded and hanging pendulously. A horizontal and rarely an erect position was however assumed by some individuals.

In the "Fauna" volume on Fresh-Water Hydroids, Dr. Annandale states that he has never seen a bud giving rise to buds while attached to the parent hydra. I have seen an instance of this phenomenon on a single occasion (August 18, 1920). This polyp was found at the bottom of the jar. It was difficult to make out the order in which the buds had arisen. There were two fairly well-developed buds, one with five tentacles and the other with six. The former had one bud and the latter two (Fig. 2). It may be suggested that the first parent polyp underwent vertical fission for some distance down the column, when budding started precociously on each of the daughter polyps. There was, however, no clear evidence to show that the colony formed was entirely due to budding or to vertical fission and budding. This branching hydra was unfortunately devoured by a dragon-fly larva a few days later, and no further observation could be made on it.

Branching in *H. oligactis* was noticed by Dr. Baini Prashad in Lahore.[1]

[1] See *Journ. As. Soc., Bengal* (N.S.) XII, page 143 (1916).

Spermaries.—From about the last week of August up to the 4th September several polyps bore spermaries. Subsequent to this date sexual activity gradually slackened and about the middle of September no polyps bearing spermaries were observed. Bud-formation recommenced, lasting for a couple of days. The polyps were very thin and transparent.

The spermaries generally arise as small mound-shaped swellings on the upper half of the column. They are, however, not restricted to this region, as occasionally several may be seen in the basal part of the column (Fig. 4). The number of spermaries apparently varies, sometimes seven or eight being formed close to one another. They are found in different stages of development, and do not seem to be arranged in a definite manner. In the more developed spermaries the active movements of spermatozoa can be observed under the low power of a microscope. As they mature a fine spray of sperms in the form of a faint white cloud is ejected from time to time from the papilliform process at their apex.

Sometimes buds are also formed simultaneously with the spermaries but they are always found below the region on which spermaries arise (Fig. 5). One after another the spermaries discharge their contents, and the polyps become very thin. A few however recommence budding, but the buds remain undeveloped.