The process of formation of the epiphragm seems to be as follows, at any rate, under artificial conditions: The animal gradually withdraws itself into the shell, the anterior part being the first to be drawn in. Later on the whole of the foot is withdrawn and the mouth of the shell is completely closed by the lobes of the mantle. The surface of these lobes is always moist and has a pitted appearance, the result of a continual wave of depressions or pits being formed on them from one end to the other. A sticky mucous-like substance is secreted by the activity of the mantle lobes which on drying becomes a thin diaphanous membrane stretching across the mouth of the shell. By further secretion the thin epiphragm becomes thick, opaque, reddish on the inside and white outside. During the process of secreting the epiphragm the animal breathes regularly, as is evidenced by the rhythmical opening and closing of the pulmonary aperture. The heart can also be seen through the shell to be pulsating regularly. When a complete epiphragm has been formed, the heart gradually ceases its pulsation and the pulmonary aperture is completely closed.

The difference in colour between the outer and inner surfaces of the epiphragm is apparently due to the action of the atmosphere on the sticky substance, the outer surface being exposed becomes white, the inner, being excluded from further contact with air and augmented by the deposition of fresh layers of the sticky substance, retains its reddish colour.

ON THE HABITS OF A HIBERNATING SPECIES OF GASTROPOD MOLLUSC FROM PASHOK (EASTERN HIMALAYAS), WITH REMARKS ON CERTAIN OTHER SPECIES.

By SUNDER LAL HORA.

In this note I have to record my observations on the habits of *Glessula* (*Rishetia*) *hastula* Benson, several specimens of which were collected in loose earth at the base of big trees in the jungle at the sides of the main road at Pashok (alt. 2,600 ft.) in the Darjeeling District. I was at Pashok from the 16th to the 21st of December 1926, and most of the observations recorded here were made during that period.

Babu D. N. Bagchi, the artist, who accompanied me on tour, collected an individual of *G. hastula* in a state of torpor on the 16th from underneath a big stone at the side of the P.W.D. Bungalow hill in a more or less shady place. On account of ill health I was keeping in bed on that day and after noticing the peculiar condition of the animal left it in a tube under my pillow. A couple of hours afterwards (about 3 P.M.) it was found that the animal had become active and was crawling about the sides of the tube with the tentacles fully expanded. About an hour afterwards it shut itself up again and did not come out though it was kept immersed in water for a considerable time. The behaviour of the animal showed that the warmth of the day, and especially its position underneath my pillow, had stimulated it to activity and that the fall of temperature in the evening had induced it to retire into its shell again in a state of torpor.

I was very busy with other matters for the next two days, but on the 19th, while going to Ghum, I left instructions with my servant to look for these molluscs at the base of big trees in loose earth. On my return late in the evening I was delighted to find a big collection of them waiting for me. All of these were in a comatose condition and were reposing inside their respective shells after having formed a series of epiphragms to save themselves from desiccation. The whole of the next day was devoted to their study. A number of them were kept in water, some were put in a tube and placed under a pillow, while the remainder were allowed to lie on a table in the open air. By 11 A.M. it was found that some of those that were left in the open air had become quite active and were crawling about on the table, while the rest were breaking the series of epiphragms in order to become free again. By about 2 P.M. all the individuals of this lot had become active. In the case of the other two lots the animals took a comparatively much longer time to regain appreciable activity. This I account for by the fact that the air in the room was much warmer (being heated by the rays of the sun throughout the day) than either the water in which the individuals were placed or the conditions afforded by the cover to those placed under the pillow. In the evening the animals withdrew again into their shells and were then preserved for laboratory study.

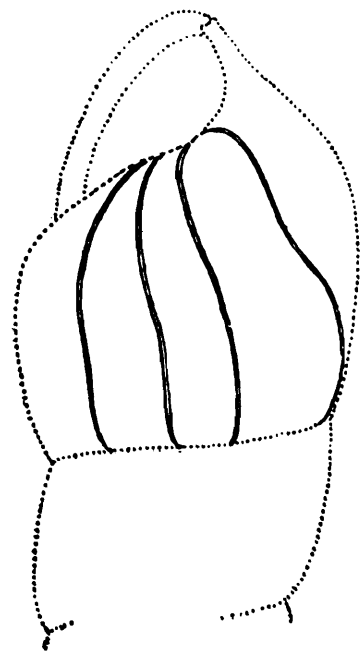
On the last day at Pashok about half a dozen individuals were collected by me on the way and were brought alive to Calcutta. For a couple of days I was very busy and could not attend to them, but on the third day I found them exactly in the same comatose condition in which they were collected at Pashok. The maximum temperature in the shade in Calcutta during this period did not rise above 79°F. A couple of individuals were placed in direct sunlight, two others were immersed in water and then taken out and kept in a moist tube in the shade, while the remaining two were left in a dry tube. Only those that were in the moist tube became active, while those in the other two lots remained in a torpid condition. This observation shows to a certain extent that direct sunlight does not of itself stimulate the activities of these animals and, secondly, that warmth in moderation along with a high degree of humidity suits them very well. There are two points of special interest that can only be investigated on the spot[1], (i) the range of this species in correlation with the altitudes at which it is found in the Eastern Himalayas and, (ii) the habits of the animal under various climatic conditions throughout the year. *Glessula hastula* was described by Benson from specimens collected by W. T. Blanford at Punkabari (alt. 1,800ft.), below Kurseong, Darjeeling District. Godwin-Austen[2] is of opinion that this species is endemic in the Eastern Himalayas and that its occurrence in other widely separated places is erroneously recorded.

As has been pointed out already, the animal secretes a series of epiphragms at the time of hibernation. As many as 5 to 6 of these thin membranes were found stretched across the lumen of the shell situated at varying distances from the mouth but chiefly inside the last

[1] Mr. R. S. Lister of the Pashok Tea Co. has very kindly promised to carry on work on the mode of life of this interesting snail.

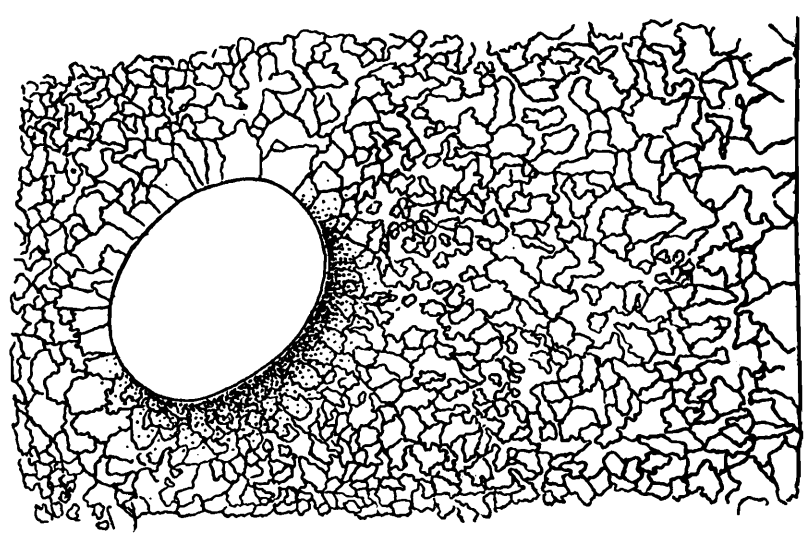
[2] Godwin-Austen, *Land and Freshwater Mollusca of India*, III, pt. I, p. 16 (1920).

whorl. An epiphragm at the mouth of the shell was found in only 7 out of 41 individuals examined and even in them the outermost cover was



TEXT-FIG. 6.—Animal of *Glessula hastula* showing a series of four epiphragms secreted during its period of hibernation. (The outline of the shell is shown by a dotted line).

cracked in places. It seems probable that either the epiphragm at the mouth is liable to injury or that the animal as a rule secretes its outermost membrane somewhat interior to the mouth. Each epiphragm is thin and translucent and is chiefly calcareous in composition as can be readily tested by the action of any dilute acid on it. The texture is cellular except at its margins and at the margins of the aperture that is

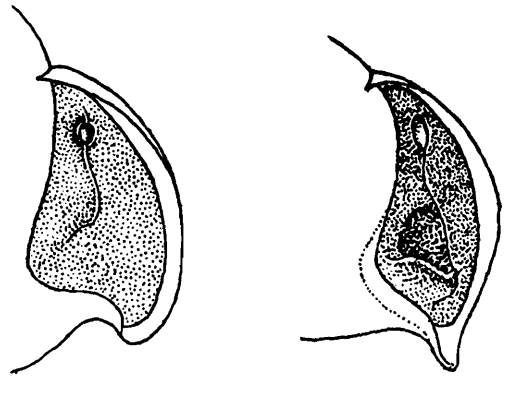


TEXT-FIG. 7.—A portion of the epiphragm of *Glessula hastula* showing the texture from its margin inward. The opening is also shown.

situated in its narrow portion, where the calcareous matter forms a regular rim. This rounded or oval aperture is situated at the top of a small pyramid and its margins are greatly thickened. In position it corresponds to the pulmonary opening of the animal, and corresponding to the line of union of the two mantle folds there is a thickened ridge on

the epiphragm running from the aperture towards its broader end. The presence of such an aperture in the epiphragm in this particular position is of the greatest use to the animal and, so far as I am aware, is a rare occurrence among hibernating gastropod molluscs. As the animal secretes a series of epiphragms, not a single one as is common in other species, so it must make provision for respiration as it gradually recedes inside the shell and the aperture is probably a very efficient device to serve this purpose.

The process of formation of the epiphragm is similar to that described by Dr. Rao for *Macrochlamys glauca* Benson. The two mantle lobes cover the entire animal when it withdraws itself inside the shell. The



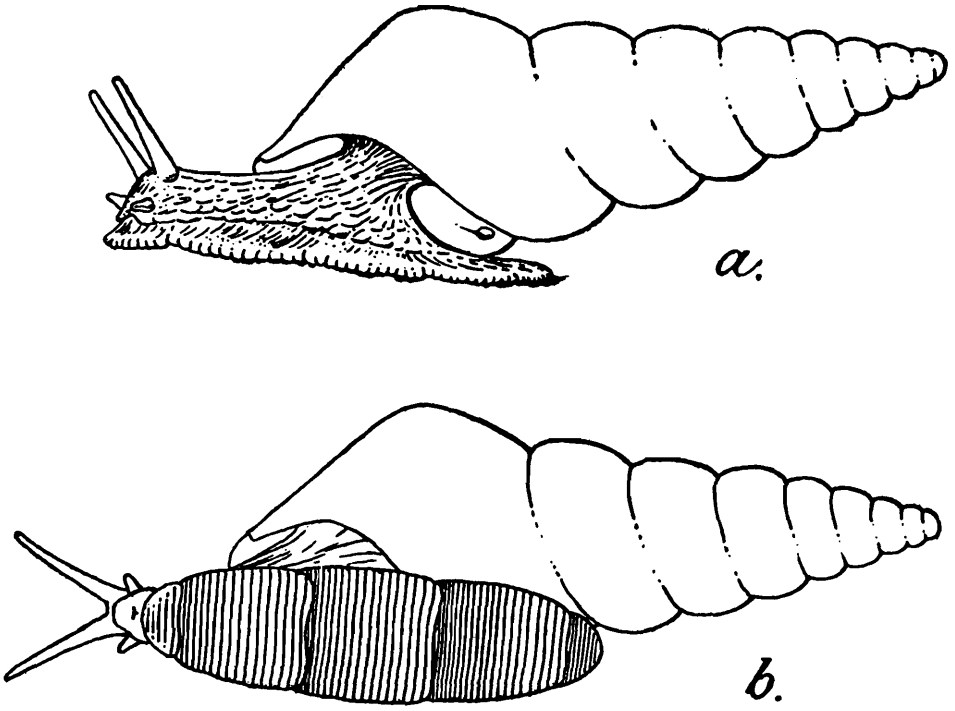
Text-fig. 8.—The epiphragm and the hibernating animal of *Glessula hastula.*

(*a*) An epiphragm at the mouth of the shell. (*b*) Comatose animal after removal of epiphragms and the 1st whorl. The black triangular area represents the position of the foot.

foot is seen through the mantle as a small triangular patch, black in colour. By the rhythmical opening and closing of the pulmonary aperture the line of union of the two mantle lobes becomes apparent. The mantle is covered with numerous white dots which are probably the glands that secrete the calcareous epiphragm.

It has been observed in *M. glauca* that the margins of the epiphragm become soft in contact with water and thus the entire structure is set free from the shell and is carried by the animal for a short time as a false operculum. In *Glessula hastula* exactly the same thing happens. An individual with the outermost epiphragm at the mouth of the shell was placed in cold water. After a short time the entire epiphragm was observed floating on the surface of the water. The animals were observed to moisten the membrane from the inside and then push it out. In this process the entire membrane was usually lifted up, though in some cases it got broken at the extreme corners where probably the fluid had not been sufficiently applied. Several specimens were found crawling about with the entire outermost epiphragm sticking to the sides of their feet. It may be remembered in this connection that the structure of the epiphragm near the margin is somewhat different from that of the rest of the plate.

The method of progression of the animal is also worth recording. A series of about four folds are seen on the foot passing from behind forwards. These divide the foot into five parts and each of these presents a corrugated appearance. These folds are not visible on the foot when the animal is stationary. The animal crawls about in jerks as can be readily seen from the movement of the shell. At the conclusion of each peristaltic motion the animal advanced a little.

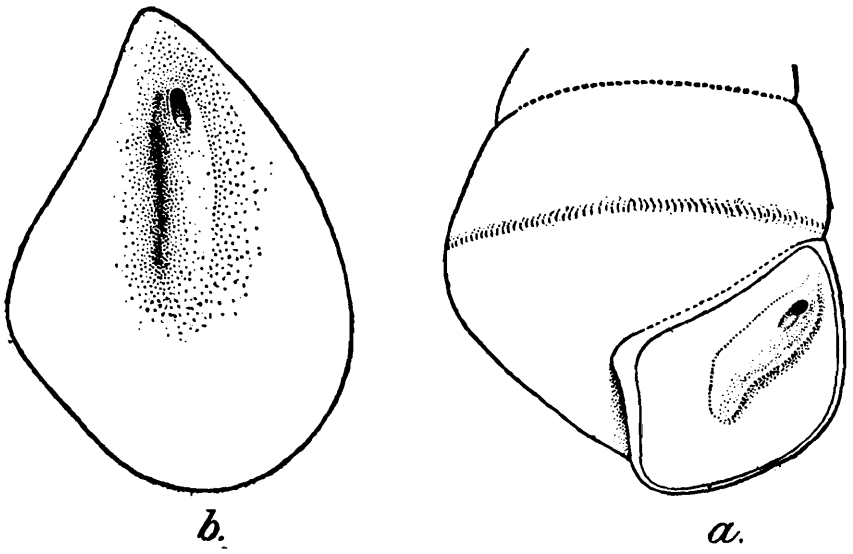


TEXT-FIG. 9.—The crawling animal of *Glessula hastula* showing definite wrinkles on the foot. *a*. Side view. *b*. Under surface.

Dr. H. Srinivasa Rao has very kindly drawn my attention to a statement made by Annandale and himself[1] regarding *Zootecus insularis* (Ehrenberg) in their account of the Molluscs of the Salt Range, Punjab, collected by me in July 1922. They say, "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 embroyonic shell. Possibly the hole had been made by some enemy which had devoured the snail." This statement is of great interest and has led me to investigate in detail the conditions present in *Zootecus insularis*. From a large number of specimens collected at various places in the Salt Range, Punjab, I have been able to find about a dozen examples in which the epiphragm was still intact and in these I have noticed a series of three epiphragms either situated very close together or at short intervals. The outermost epiphragm is thicker than the inner two, which decrease in thickness as they recede from the mouth. In a com-

[1] Annandale and Rao, *Rec. Ind. Mus.* XXV, pp. 394, 395 (1923).

plete epiphragm there is a small hole towards the upper extremity, situated at the end of an elevated and tunnel-like portion of the epiphragm.



TEXT-FIG. 10.—Epiphragm secreted by the aestivating animal of *Zootecus insularis* (Ehrenberg).

a. An epiphragm *in situ* × 10. *b*. An epiphragm showing its general form × 18.

The hole is of a variable size and probably, in the specimen examined by Annandale and Rao, the elevated portion in the series of epiphragms had been damaged by some enemy for the purpose they suggest and thus an " elongate transverse hole " was left in each epiphragm.

The structure of the epiphragm is similar to that described for *Glessula hastula*. I could take off complete epiphragms by shaking a dead shell in a glass tube. This shows that there is a special area at the margin of the epiphragm coming in contact with the shell that is of a different consistency.

I would also like to clear up an ambiguity that occurs in Strickland's statement about " *Nanina vitrinoides* (Deshayes)" quoted by Dr. Rao in the preceding paper. He mentions a succession of two or three ' *pomata* ' formed one within the other during a process of desiccation. I presume that he does not mean the formation of two or three complete epiphragms, one within the other as is usual in *Glessula hastula* and *Zootecus insularis*, for in " *Nanina vitrinoides* " no hole is left in the epiphragm for purposes of respiration. He may either mean that on the removal of one epiphragm the animal is capable of secreting another further into the shell or, as sometimes happens, that the animal starts to form an epiphragm but before this is entirely completed a portion of it dries and curls up and then the animal starts afresh. There may thus be a succession of 2 or 3 epiphragms in one individual.

I have noticed such a series of epiphragms in certain specimens of *Macrochlamys glauca* Benson, kept under observation in our laboratory in Calcutta.

I may also point out here that a large number of specimens of *Buliminus* (*Subzebrinus*) *dextrosinister* Annandale and Rao, collected by me in the Salt Range, were found attached to tree trunks in an apparently

comatose condition, but at that time I did not notice their method of aestivation in detail. Dr. Rao informs me that he has seen on several occasions specimens of *Ariophanta* in South India attached to *Cactus* plants in the dry season in a state of aestivation. These instances are mentioned here in order to elicit further information about them.