From the Journal of the Asiatic Society. Science.
Vol. XVIII, No. 2, 1952.

RESPIRATORY ADAPTATIONS OF TORRENTIAL FISHES, WITH SPECIAL REFERENCE TO THE GLYPTOSTERNOID FISHES OF THE FAMILY SISORIDAE: (ORDER SILUROIDEA)

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(*Received on 22nd November, 1951*)

(Communicated by Dr. S. L. Hora)

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Introduction.

In a series of articles, Dr. S. L. Hora has shown that some of the morphological characteristics and biological features of torrential animals are determined by a group of physical conditions, such as, swiftness of current, coolness of water, richness of oxygen, nature of substratum, type of shelter, etc., and in this connection he has drawn repeated attention to certain adaptive modifications undergone by torrential fishes for respiratory purposes. The normal method of respiration is by taking in water through the mouth, which is generally extensive and is anterior or superior in position, and expelling it through the gill openings, which are fairly extensive with a very narrow isthmus on the ventral surface. The exacting environmental factors, so characteristic of the torrential streams, have brought about in highly specialized fishes diverse adaptations, the most important being the necessity to resist the swift current and prevent themselves from being washed away. The habit of lying close to the substratum and adhering to the rocks by means of the ventral surface of the body in these highly specialized hill-stream fishes has ultimately resulted in the modification of the entire respiratory mechanism. In such cases the mouth is ventral or subterminal in position and the isthmus is also much wider.

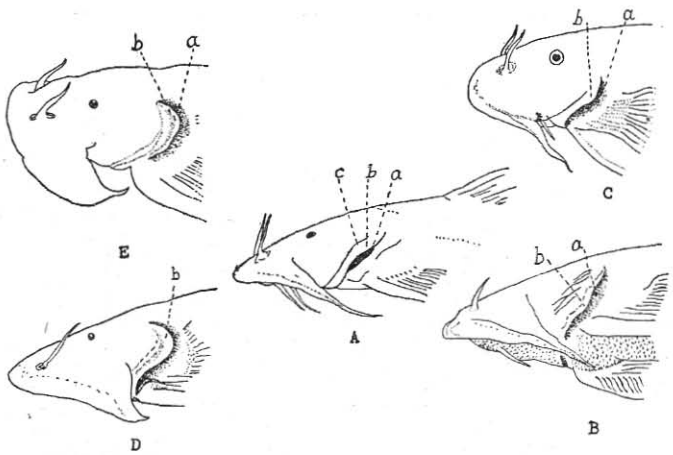
It is generally agreed that the respiratory metabolism (oxygen consumption) in poikilothermous animals tends to vary directly with the temperature to which they are subjected. Hence, the cold and rapid waters of the torrential streams being highly oxygenated, the fishes living in them are favourably placed as far as the oxygenation of the blood is concerned.

GLYPTOSTERNOID FISHES AND THEIR ADAPTATIONS.

In this article, it is proposed to deal with the respiratory adaptations of one such group of torrential fishes, viz., the Glyptosternoid fishes of the family Sisoridae, the Systematics (now under publication in the *Rec. Ind. Mus.*, Vol. XLIX for 1951), and the Evolution and Distribution of which have been recently studied. They constitute a remarkable group inhabiting the torrential streams of certain parts of South-East Asia. Like the Cyprinoid families Homalopteridae and Gastromyzonidae of South-East Asia, they are also greatly flattened forms, in which the head and the body are considerably depressed and the outer halves of the paired fins and the ventral profile are flattened and horizontal.

Ecological conditions and geographical isolation have brought about a great diversity of form and structure in the Glyptosternoid fishes. The genera and species are distinguished on the characters of dentition, nature of the gill-openings, nature of the labial fold, extent of the pectorals in relation to the pelvics, number of rays in the paired fins, etc. Of these, the first three, are directly associated with respiration in these fishes. As in the Homalopteridae and Gastromyzonidae, according to the variations in the extent of the gill-openings, the Glyptosternoid fishes may be grouped under the following categories:—

(1) Gill-openings extend to the ventral surface for a short distance.
(2) Gill-openings extend to opposite the base of the pectoral spine dorsally.
(3) Gill-openings greatly restricted and hardly extend to the pectoral spine.



TEXT-FIGURE 1. Lateral view of head and anterior part of body of Glyptosternoid fishes showing the extent of the gill-opening. *a*—gill-opening; *b*—opercular flap; *c*—limit of bony operculum.

(A) *Glyptothorax pectinopterus* (McClell.) (after Hora, 1934.)
(B) *Glyptosternum reticulatum* McClelland.
(C) *Exostoma labiatum* (McClelland).
(D) *Euchiloglanis sinensis* Hora and Silas.
(E) *Euchiloglanis hodgarti* (Hora).

The table given below shows at a glance the distribution of these characters in the different species of Glyptosternoid fishes.

No.	Name of species.	Gill-openings extend to:— (1) above base of pectoral spine.	(2) opposite base of pectoral spine.	(3) ventral surface for short distance.
1	*Glyptosternum reticulatum* McClelland	—	—	×
2	*Glyptosternum maculatum* (Regan) ..	—	—	×
3	*Glyptosternum akhtari* Silas ..	—	—	×
4	*Coraglanis kishinouyei* (Kimura) ..	×	—	—
5	*Euchiloglanis hodgarti* (Hora) ..	×	—	—
6	*Euchiloglanis davidi* (Sauvage) ..	×	—	—
7	*Euchiloglanis myzostoma* Norman ..	×	—	—
8	*Euchiloglanis feae* Vincigerra ..	×	—	—
9	*Euchiloglanis sinensis* Hora and Silas	—	×	—
10	*Euchiloglanis macrotrema* Norman ..	—	×	—
11	*Myersglanis blythi* (Day) ..	—	×	—
12	*Glaridoglanis andersonii* (Day) ..	×	—	—
13	*Oreoglanis macropterus* (Vinciguerra)	—	×	—
14	*Oreoglanis siamensis* Smith ..	×	—	—
15	*Exostoma berdmoeri* Blyth. ..	×	—	—
16	*Exostoma yunnanensis* (Tichang) ..	×	—	—
17	*Exostoma vinciguerrae* Regan ..	—	×	—
18	*Exostoma stuarti* (Hora). ..	—	×	—
19	*Exostoma labiatum* (McClelland) ..	—	×	—

With the exception of *Glyptosternum*, in all other genera the gill-openings are restricted to the dorso-lateral sides and do not extend to the ventral surface. The genus *Coraglanis*, which resembles *Glyptosternum* in general facies and in the nature of the dentition, is easily distinguished from the latter by its greatly reduced gill-openings. Specific variations exist as to the relative extent of the gill-openings in the genera *Euchiloglanis*, *Oreoglanis* and *Exostoma*. In the genus *Myersglanis*, the aperture extends to opposite the base of the pectoral spine dorsally, whereas in *Glaridoglanis* they are greatly restricted.

Mode of Respiration in Glyptothorax.

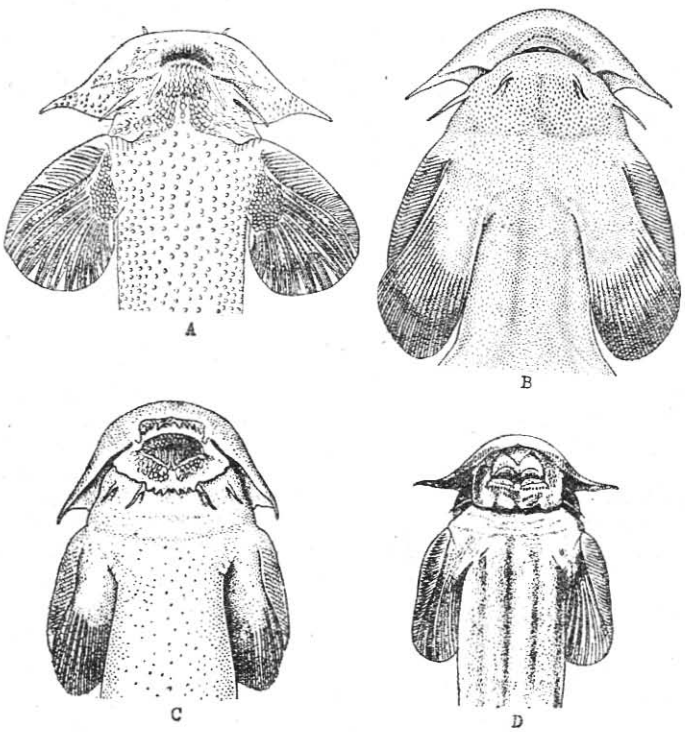
Speaking of the respiratory movements of another Sisorid, viz., *Glyptothorax* Blyth, Hora (1923) observed:

'In members of the genus *Glyptothorax*, the gill-openings are fairly wide and those of the two sides are separated by a narrow isthmus on the under surface, but for purpose of respiration, the aperture is divided into three portions, (1) a small upper portion which by its continuous flapping guides the expiratory current. This portion is provided with a well-marked membrane; (2) next is the portion between (1) and the base of the pectoral fin. This only opens when the fish takes a deep breath and throws out any undesirable particles that may have entered the gill-cavity; (3) the last portion is represented by a slit on the under surface of the body and is never opened for respiratory purposes. In fact, it is as I can see merely vestigeal and, is of no use to the fish.'

Glyptothorax closely resembles *Glyptosternum* McClelland and differs from it only in the first ray of the dorsal and the paired fins being spinous and strong and also in the possession of an adhesive apparatus on the chest. In the nature of the gill-openings, the fishes of these two genera are alike. Moreover, *Glyptothorax* also inhabits the torrential streams. Though no direct observations have yet been recorded on the respiratory movements of *Glyptosternum*, the nature of the mouth, gill-openings, gill-flaps, etc., suggest that they should be more or less similar to those of *Glyptothorax*.

Rôle of Dentition and Lips in Respiration.

On the position of the teeth, mouth, lips and associated structures, the Glyptosternoid fishes may be broadly divided into two categories, viz., those genera in which the labial fold and the labial groove are continuous (*Exostoma*, *Oreoglanis*, and *Myersglanis*) and those in which the labial fold is widely interrupted and consequently the labial groove is also not continuous (*Glyptosternum*, *Coraglanis*, *Euchiloglanis* and *Glaridoglanis*).



Text-figure 2. Ventral view of the Glyptosternoid fishes showing the nature of the mouth, lips and associated structures.

(A) *Glyptosternum reticulatum* McClelland.
(B) *Euchiloglanis hodgarti* (Hora).
(C) *Oreoglanis siamensis* Smith.
(D) *Exostoma labiatum* (McClelland).

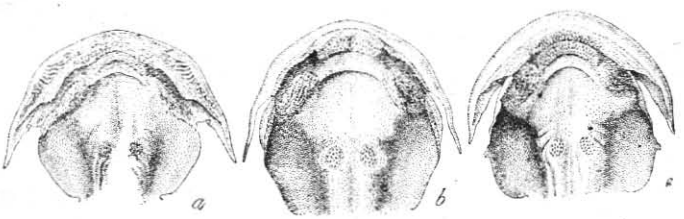
It is of interest to note that in the first group, where the labial fold is continuous, the teeth are also exposed, whereas, with the situation of the teeth well within the mouth, the labial fold is also widely interrupted. As owing to the position of the tooth bands the mouth cannot be completely closed in *Exostoma*, *Oreoglanis* and *Myersglanis*, the suctorial lip in these fishes might have arisen as a respiratory adaptation, so as to prevent the outflow of water through the mouth during the expiratory phase of respiration. Now they serve both at the time of respiration and when the fish wants to secure a firm hold on the substratum. In both cases the purpose of the expanded lips is adhesion. In *Glyptosternum* and other genera, where the labial fold is broadly interrupted, the function of adhesion is more or less relegated to the fins and consequently the lips are also not reflected and

spread round the mouth. It is probable, however, that they live in deeper waters, where the swiftness of the current does not affect them to the same extent as in the small shallow torrential streams.

Gill-openings and Pharyngeal Chamber.

With the reduction of the gill-openings and the small size of the mouth, it is obvious that the volume of the respiratory current is also considerably reduced. Due to the high percentage of oxygen contained in the cool waters of the torrential streams, the quantity inhaled at a time is sufficient to carry on normal respiratory activities for a longer period than in fishes living in the slow flowing warmer streams of the plains. The suspension of respiratory activities for short intervals would thus enable the fish to adhere to the substratum in the swift currents, especially during times of floods. As such it would be advantageous if the fish possesses some sort of 'receptacles' for the shortage of water. On dissection it was found that the pharynx and the gill-cavities have undergone certain modifications to enable them to accommodate and store more water.

In *Glyptosternum reticulatum*, where the gill-openings are wide and extend to the ventral surface for a short distance, the roof of the mouth and the sides of the gill-chambers are slightly depressed to form shallow depressions. In this species as in *Glyptothorax* (p. 175, *vide supra*) the opercular membrane is broad in its outer half. In both cases, the expiratory current



Text-figure 3. Dissection of the ventral surface of the buccal cavity and gill-chambers of:

(*a*) *Glyptosternum reticulatum* McClelland.
(*b*) *Exostoma labiatum* (McClelland).
(*c*) *Euchiloglanis hodgarti* (Hora).

is guided by the continuous flapping of this portion of the operculum, the rest being closely pressed to the sides of the body and not being much used. Inhalation is through the mouth and stored water is probably expelled at intervals. A slight rising of the thick and fleshy lip would help the fish to take in fresh quantities of water. How far, the labial and rostral groove would serve for conducting water to the mouth is not known. The numerous minute papillae surrounding the lips and the mouth in these fishes are adhesive in function as described by Bhatia (1950) in the case of *Glyptothorax telchitta*. The situation of the teeth within the mouth helps it to close the mouth firmly during expiration.

In *Exostoma labiatum*, where the gill-openings extend to opposite the base of the pectoral fin dorsally, the 'pouches' or depressions are more developed and marked in outline than in *G. recticulatum*. The teeth being exposed, the continuously reflected labial fold in this species helps in keeping the mouth firmly closed during expiration.

Euchiloglanis hodgarti, in which species the gill-openings are very much restricted, have the 'receptacles' well developed. The well developed opercular membranous flap in this species would help to a certain extent, with its constant movement, in the expulsion of water during expiration. The internal position of the teeth facilitates the closure of the mouth during this phase.

An intermediate condition between the greatly reduced gill-opening, and its extent opposite to the pectoral spine is seen in *Euchiloglanis sinensis*. Here the opercular portion shows the development of a ridge at its lower half which closely fits into a groove on the elevated portion found correspondingly at the base of the pectoral spine. It is evident that the lower region which is more or less non-functional, is in the process of closing up, thus to a certain extent foreshadowing the condition where the gill-openings are restricted to small apertures well above the base of the pectoral spine.

BRANCHIAL STRUCTURES.

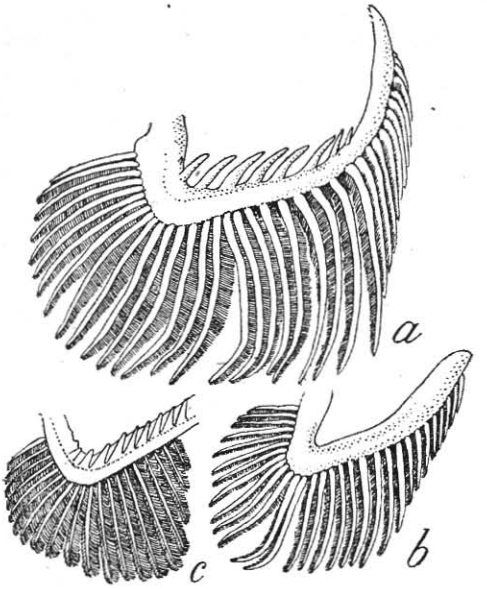
An examination of the branchial structure in *G. reticulatum*; *E. hodgarti* and *E. labiatum* were made in order to find out the changes that they have undergone. The number of specimens, their standard length, the number of gill-filaments and their length are given below:

Name of species.	Number of specimens examined.	Standard length in mm.	Approximate number of gill-filaments in 3rd Br. arch.	Average length of gil-filaments in mm.
Glyptosternum reticulatum. McClelland ..	6	90–98	65–75	3·5–4
Exostoma labiatum (McClelland) ..	3	58–60	60–63	2·5
Euchiloglanis hodgarti (Hora) ..	4	78–80	40–50	2

Though specimens of the same length of the three species could not be obtained for study, still it is seen that in *Glyptosternum reticulatum*, where the gill-openings extend to the ventral surface and the receptacles are very shallow, the gill-filaments are also comparatively longer and larger in number. Well developed gill-rakers are also present on the branchial arches. The branchiae are less numerous, but compactly arranged. From the large surface area exposed it would seem that *G. reticulatum* takes in the respiratory current more frequently.

In *Euchiloglanis hodgarti* the gill-filaments on the branchial arches are fewer and comparatively not as long as in *G. reticulatum*. But the branchiae are numerous and each filament gives the appearance of a feather. An intermediate stage between *G. reticulatum* and *E. hodgarti* is seen in *Exostoma labiatum*. In the last two species the gill-openings are restricted and the 'receptacles' are well developed. Thus, in these fishes there is a reduction in the length of the gill-filaments, but at the same time the branchiae and the receptacles are much better developed. This would enable the fish to accommodate and store more water for respiration. The inner walls of the pharyngeal cavity may also help in the absorption of oxygen. This adaptative modification would seem to help the fish in suspending its respiratory activities for short periods during heavy floods and thus enable the large reflected lips round the mouth to adhere to the substratum in the swift currents.

No such extreme adaptation, as a separate incurrent and excurrent openings into the branchial chamber in the region of the gill-opening, as



TEXT-FIGURE 4. Structure of the branchial arch in:
(*a*) *Glyptosternum reticulatum* McClelland.
(*b*) *Exostoma labiatum* (McClelland.)
(*c*) *Euchiloglanis hodgarti* (Hora).
(Gill-filaments on the outer side of the branchial arch are only shown.)

seen in the Cyprinoid genus *Gyrinochilus* of Borneo and Siam or the Catfish *Arges* of the Andes of South America, is met with in the Glyptosternoid fishes. Though Smith (1934, p. 294) suggested the possibility of a similar mode of respiration in *Oreoglanis siamensis*, it seems highly doubtful. According to Smith:

'There is no evidence of a current of water into the mouth and out of the branchial openings. It is possible that the feeble current of water through the restricted branchial opening is induced simply by the movement of the gill-flaps.'

The restricted gill-openings of *O. siamensis* would seem to obviate any need for constantly taking in fresh quantities of water for respiratory purposes. It also seems likely that the fish is capable of storing water in the gill-chambers and thereby of suspending respiratory movements for short periods.

RESPIRATORY CONVERGENCE AND CONCLUSION.

In the Homalopteridae and Gastromyzonidae, Hora and Law (1942) found that the reduction of the gill-opening and the development of large pharyngeal gill-spaces for the storage of water seem to go hand in hand. The same is true with the Glyptosternoid fishes also. According to Hora (1935), in the evolution of the storage cavities, these torrential fishes show a parallel development to the air breathing fishes of India, such as, *Periophthalmus* Bloch and Schneider, *Periophthalmodon* Bleeker, *Boleophthalmus* Valenciennes, *Pisoodonophis* Kemp., *Taenioides* Lacépède, *Apocryptes* Valenciennes, *Pseudapocryptes* Bleeker, etc., in which the pharyngeal lining

of the gill chambers seems to serve as the main respiratory organ. These air breathing fishes could also suspend their breathing for considerable periods after gulping in fresh air.

In conclusion it may be noted that the directiveness of such adaptive trends in the Glyptosternoid fishes cannot be denied. This is so, especially because, in the region of the Eastern Himalayas, Tibet, and China the tempestuous environment of the torrential streams having been repeatedly intensified by the Pleistocene orogenic movements, provided factors of sufficient importance for inducing such adaptations which ultimately resulted in the evolution of these fishes.

Acknowledgment.

I am deeply indebted to Dr. S. L. Hora, Director, Zoological Survey of India, for the facilities he gave me to work on this problem and for his helpful suggestions and guidance in the preparation of the paper.

Summary.

The respiratory modifications of the Glyptosternoid fishes are discussed in the light of their correlations with the habitat and form of the fish. The probable causes which led to the reduction of the gill-openings and the formation of the receptacles for the storage of water are explained, and the modifications resulting in the reduction of the gill-filaments and the better development of the receptacles are described. An account of the lips and associated structures in the Glyptosternoid fishes is given and the probable function of the various structures explained. Attention is directed to the close parallelism between the respiratory adaptations of the Glyptosternoid fishes and the Cyprinoid families Homalopteridae and Gastromyzonidae and also the bucco-pharyngeal chambers of certain air-breathing fishes of India.

References.

Bhatia, B. (1950). Adaptive modification in a hill-stream Catfish, *Glyptothorax telchitta* (Hamilton). *Proc. Nat. Inst. Sci. India*, XVI(4), pp. 271–285.

Das, B. K. (1927). The bionomics of certain air-breathing fishes of India, together with an account of the development of their air-breathing organs. *Phil. Trans. Roy. Soc. London*, (B), CCXVI, pp. 183–212.

Hora, S. L. (1923). Observations on the fauna of certain torrential streams in the Khasi Hills. *Rec. Ind. Mus.*, XXV, p. 593.

Hora, S. L. (1932). Mechanism of respiration in Hill-stream fishes. *Curr. Sci.*, I, pp. 34–36.

Hora, S. L. (1934). Respiration in fishes. *Journ. Bomb. Nat. Hist. Soc.*, XXXVI, pp. 538–560.

Hora, S. L. (1935). Physiology, bionomics and evolution of air-breathing fishes of India. *Trans. Nat. Inst. Sci. India*, I, pp. 1–16.

Hora, S. L. and Law, N. C. (1942). Respiratory adaptation of South Indian Homalopterid fishes. *Journ. Roy. Asiat. Soc. Bengal*, VIII, pp. 39–46.

Hora, S. L. and Silas, E. G. (1951). Notes on Fishes in the Indian Museum. XLVII. Revision of the Glyptosternoid fishes of the family Sisoridae, with description of new genera and species. *Rec. Ind. Mus.*, XLIX (1), pp. 5–29.

Hora, S. L. and Silas, E. G. (1951). Evolution and Distribution of the Glyptosternoid fishes of the family Sisoridae (order Siluroidea). *Proc. Nat. Inst. Sci. India*, XVIII (4), pp. 309–322.

Smith, H. M. (1931). Notes on Siamese Fishes. Respiratory movements in *Gyrinocheilus*. *Journ. Siam. Soc. Nat. Hist. Suppl.*, VIII, pp. 11–14; 187–189.

Smith, H. M. (1934). Contributions to the Ichthyology of Siam. X. Notes on the mountain Catfish *Oreoglanis*. *Journ. Siam. Soc. Nat. Hist. Suppl.*, IX (3), pp. 293-294.