ADAPTIVE MODIFICATIONS IN A HILL-STREAM CATFISH, *GLYPTOTHORAX TELCHITTA* (HAMILTON).

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(Communicated by Dr. S. L. Hora, F.N.I.)

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Since 1920, in a large series of papers, Dr. Hora has thrown considerable light on the ecology, bionomics and evolution of torrential fishes, with special reference to the adaptive modifications undergone by them in response to a rocky substratum and swift currents. Structural modifications of different organs in various types of hill-stream fishes have been dealt with by a number of other workers but, so far as I am aware, no single species of fish has been studied exhaustively. Dr. Hora, therefore, suggested to me the problem of investigating a small catfish, *Glyptothorax telchitta* (Hamilton), and placed some well-preserved material at my disposal for study. During the progress of work I had occasions to discuss my results with Dr. Hora. His knowledge of the habits and habitats of the species has been of great value in understanding the functional morphology of the modifications noticed.

Glyptothorax telchitta was described by Hamilton in 1822, but its precise systematic position has been recently elucidated by Hora and Menon in an article to be published in the *Records of the Indian Museum*. The fish belongs to the order Siluroidea and the family Sisoridae. It is moderately specialized for life in swift currents and is usually found in small, shallow pebbly channels with water flowing at the rate of 6 to 8 feet per second. The general body-form is torpedo-shaped, thus permitting water to flow over it without forming eddies at the posterior end.

The material for this investigation was obtained by Dr. Hora from the Rihand river, near the Pipri Dam Site, in the Mirzapore District, U.P. The fish were fixed in alcoholic Bouins fluid and, after treatment in 70% alcohol, preserved in rectified spirit. Free hand sections, dissections and 5 to 8μ thick microtome sections stained with Haematoxylin, Eosin and Iron Haematoxylin were prepared in carrying out these investigations.

I wish to express my deep gratitude to Dr. S. L. Hora for suggesting the problem, giving the material and for watching the progress of work. The work was done under the supervision of Dr. M. L. Bhatia, Zoological Laboratory, University of Delhi, and my sincere thanks are due to him for constant advice and help. I am also thankful to the University authorities for affording me facilities for carrying out these investigations.

It is proposed to deal with the subject in a series of articles, the first dealing with adhesive organs is presented here.

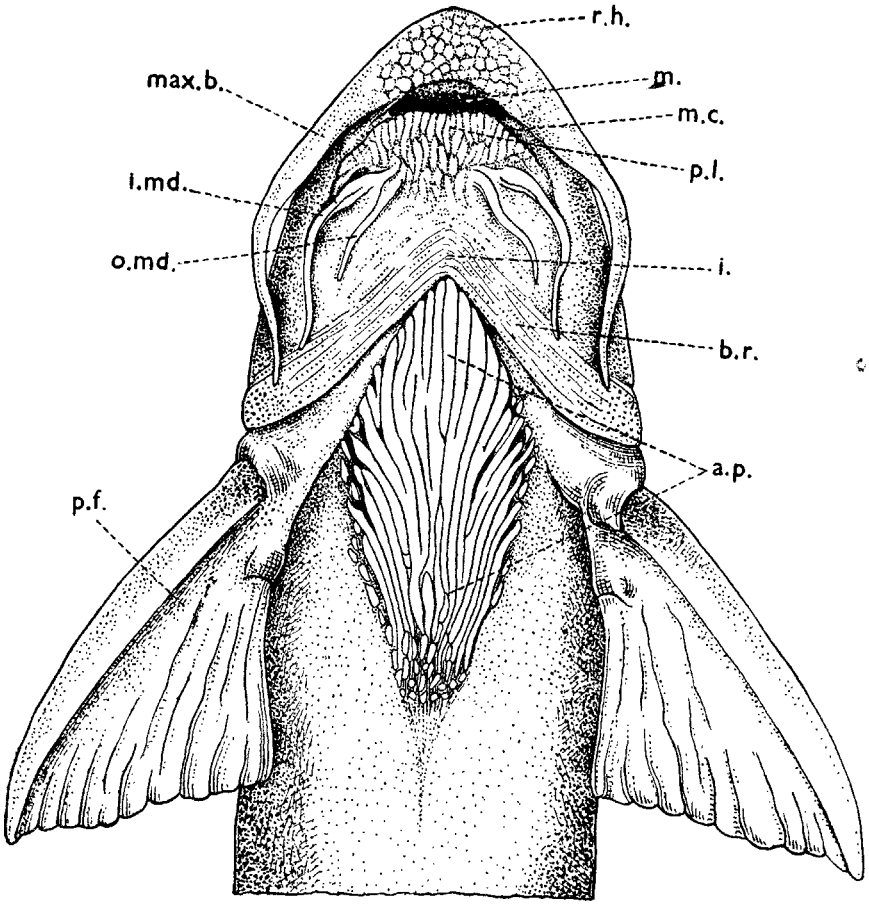
Part I. EPIDERMAL ADHESIVE ORGANS.

Our knowledge of adhesive organs is based chiefly on the work of Hora (1922) who gave an account of these organs in a number of fishes and *inter alia* dealt with those of *Glyptothorax* (= *Glyptostermun*) also. He gave certain histological details but his material was not specially preserved for such studies. Wu and Liu (1940) seemed to have overlooked Hora's work and described the structure of the adhesive organs of a Chinese species of *Glyptothorax*.

A satisfactory account of the structure of adhesive organs is not available in literature, and besides this there are details in the general make up and in the histological structure of the adhesive organ which still need elucidation.

This paper, in addition to giving accurate histological details of the parts modified as adhesive organs, gives also the way different structures are formed, as also the manner in which they function.

The adhesive organs of *G. telchitta* (Text-fig. 1) are associated with the following structures:—



TEXT-FIG. 1.—*Glyptothorax telchitta* (Hamilton). Ventral view of anterior portion of head and body.

a.p., adhesive pad; *b.r.*, branchiostegial region; *i.*, isthmus; *i.md.*, inner mandibular barbel; *m.*, mouth; *max.b.*, maxillary barbel; *m.c.*, mouth channel; *o.md.*, outer mandibular barbel; *p.f.*, pectoral fin; *p.l.*, posterior lip; *r.h.*, rostral hood.

(i) *The Rostral Hood* (Text-figs. 1, *r.h.* and 2*a*, 2*b*) or the region in front of the mouth and covering the anterior lip.

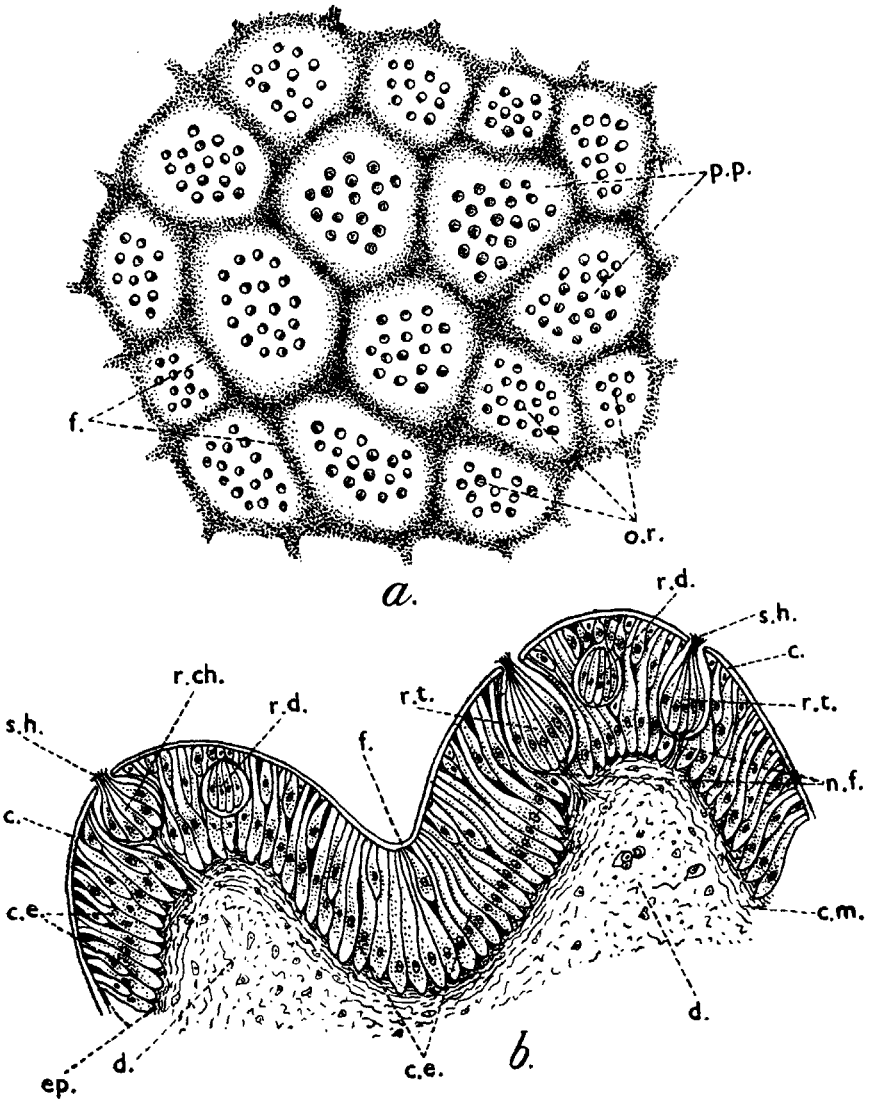
(ii) *The Posterior Lip* (Text-figs. 1, *p.l.*, and 3*a*, 3*b*) or the region behind the mouth.

(iii) *The Maxillary barbels* (Text-figs. 1, *max.b.* and 5).

(iv) *The Region of the Branchiostegial Rays* (Text-figs. 1, *i.* and *b.r.* and 6).
(v) *The Thoracic Adhesive Apparatus* (Text-figs. 1, *a.p.* and 7, 8).

In the following account, the structure of the various regions is considered separately.

(i) The *Rostral hood* (Text-figs. 1 and 2*a*, 2*b*).



TEXT-FIG. 2.—*Glyptothorax telchitta* (Hamilton). Structure of the rostral hood.

a. Flat mount of a small portion of the rostral hood showing polygonal papillae; *b*. Section through rostral hood papillae.

c., cuticle; *c.e.*, columnar epithelial cells; *c.m.*, circular muscle layer; *d.*, dermis; *ep.*, epidermis; *f.*, furrow; *n.f.*, nerve fibre; *o.r.*, openings of receptors; *p.p.*, polygonal papillae; *r.ch.*, chemo-receptor; *r.d.*, developing receptor; *r.t.*, tango-receptor; *s.h.*, sensory hair.

With the shifting of the mouth to the ventral surface, some distance behind the snout, the rostral skin is also carried over to the ventral surface to such an extent as to cover and to mask the anterior lip. This region assumes the appearance of a small pad-like structure in front of the mouth. Under a magnifying lens, the integument here looks profusely papillated and appears to subserve an adhesive function. A lightly stained flat mount of the peeling of this region shows under the microscope a polygonal pattern, (Text-fig. 2*a*), each polygonal area representing a papilla. On the summit of each papilla is seen a group of 5 to 20 minute circular apertures which, as seen in a section of the papillae, are the external openings of as many receptor organs.

In a section (Text-fig. 2*b*), each papilla is a more or less conical elevation formed both by the dermis and epidermis. The epidermal layer consists of closely packed spindle-shaped columnar epithelial cells. The entire papilla forms a conical projection on which, as already stated, open 5 to 20 receptors. Text-fig. 2*b* is of a section passing through two papillae showing three complete and two developing receptors. Each epidermal cell consists of finely granular cytoplasm and has a centrally placed oval nucleus.

A receptor consists of a group of 10 to 15 long slender cells, placed within a flask-shaped cavity. The cytoplasm of the receptor-cells is uniformly granular and a small oval nucleus is placed in the centre of each cell. Each receptor-cell bears fine hair-like processes at its free outer end. The receptors receive their nerve supply at the base, and from their general shape and from the manner of their taking stain, it has been possible to recognize two types of receptors in each group on a papilla, which are presumably Tango-receptors (flask-shaped) and Chemo-receptors (spherical), performing taste and olfactory functions respectively.

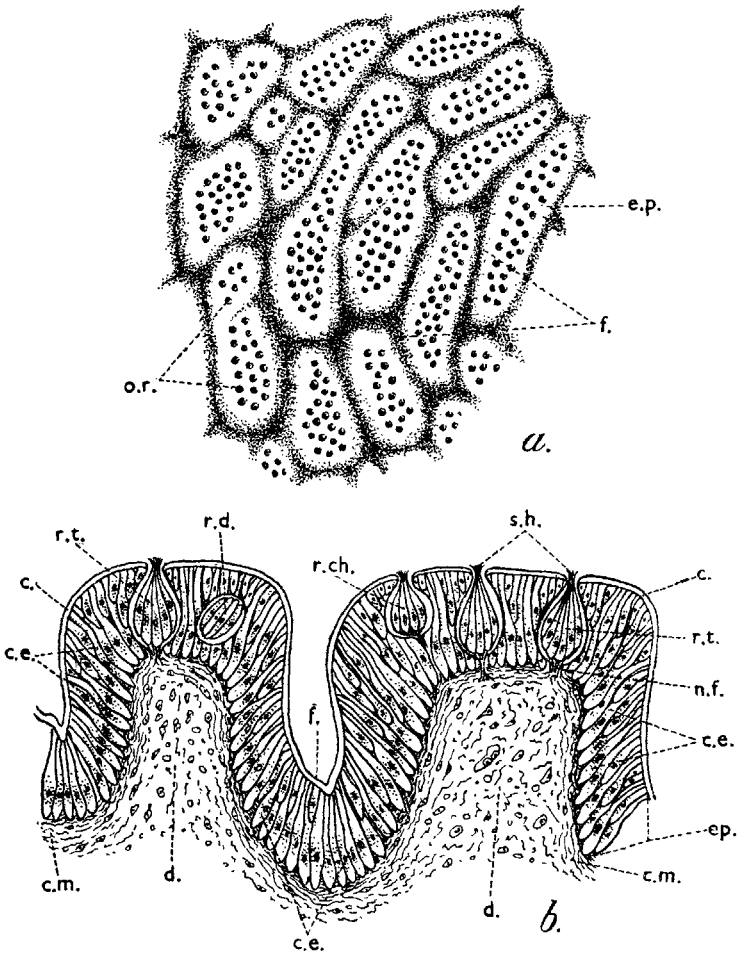
The receptors are modified epidermal cells, and within the series of sections one invariably comes across receptors in the process of formation. In some well stained, properly differentiated sections, it has been possible to see epidermal cells in active state of division, and various developing stages of these receptors. The epidermal cells destined to form receptors, group together, sink deep within the epidermis, and come to lie within a space, before they project out, and start functioning.

(ii) The *Posterior Lip* (Text-figs. 1 and 3*a*, 3*b*).

The region immediately behind the mouth may be called the posterior lip. From the position of the mouth, as also of the two lips, it is more appropriate to call these anterior and posterior instead of upper and lower lips. There is a distinctly marked region behind the mouth which is papillated. The epidermis resembles that of the rostral hood and is highly papillated, only the papillae are longish and considerably extensive. They are in the form of long ridges, more well-defined and elevated than those described in the case of the rostral hood. This region appears to be carrying a greater strain than the rostral hood and oblong nature of papillae appears to have secondarily developed as a result of fusion of number of polygonal papillae. In between the long ridges, one notices polygonal papillae of the type seen on the rostral hood, and at some places, 2, 3 or even 4 polygonal papillae combining together to form a long ridge. The summit of each ridge is flat, on which open a large number of receptors, similar to those described in the case of the rostral region. The ridges are well-defined and have steep edges. The histological details of each papilla, and the receptors on these papillae are similar to those found in the rostral region.

The integument behind the posterior lip is not papillated, though it exhibits polygonal pattern, each polygon bearing a group of 4 to 5 receptors. The structures which remained obscure to Ramsay Wright (1884) in the integument of *Amiuris catus*, and which later in *Garra* and *Glyptosternum* (= *Glyptothorax*) were very hesitatingly described by Hora, as gland-cells, are really the receptors. The histological details figured and described by him in *G. labiatum* (Text-fig. 4) are very

similar to those figured here and leave no doubt in my mind about their being receptors even in those forms. After examining the microscopical preparations, Dr. Hora has confirmed my findings and interpretations of these structures as receptors.



TEXT-FIG. 3.—*Glyptothorax telchitta* (Hamilton). Structure of the posterior lip.

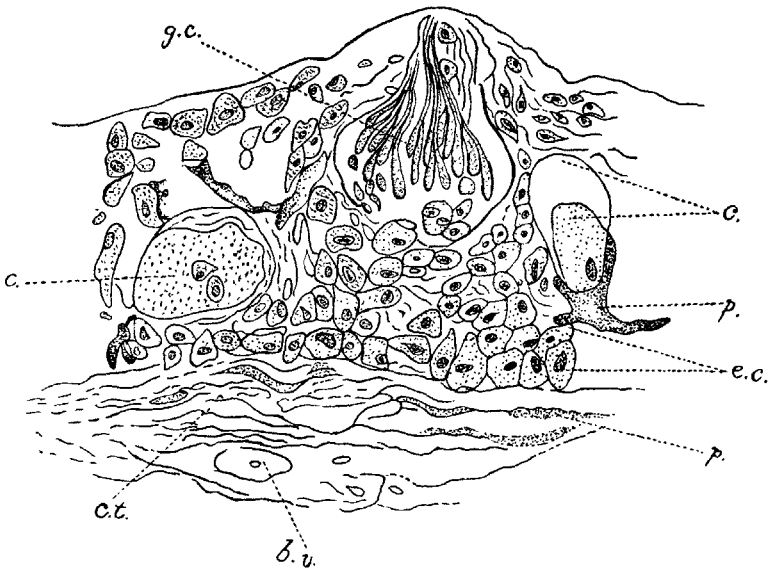
a. Flat mount of small portion of the posterior lip; *b*. Section through the posterior lip papillae.

c., cuticle; *c.e.*, columnar epithelial cells; *c.m.*, circular muscle layer; *d.*, dermis; *ep.*, epidermis; *e.p.*, elongated papillae; *f.*, furrow; *n.f.*, nerve fibre; *o.r.*, openings of the receptors; *r.ch.*, chemo-receptor; *r.d.*, developing receptor; *r.t.*, tango-receptor; *s.h.*, sensory hair.

As to the rostral hood and posterior lip papillae, it may be recalled that in similar papillae on the rostral hood and lower lip of *Garra*, described and figured by Hora (1922, p. 47), the superficial epidermal layer is modified into spines and there are no receptors. Whereas in *Garra* these papillae act as frictional devices, in *Glyptothorax* they seem to function as adhesive organs through adpression. The large number of receptors round the mouth are probably gustatory in function and taste the water flowing into the mouth for respiratory purposes.

(iii) *The Maxillary barbel* (Text-figs. 1 *max. b.* and 5).

The anterior lip has fleshy backward extensions on the two sides which terminate behind into a pair of cylindrical barbels. Each barbel as seen in a transverse section (Text-fig. 5) has a cartilaginous axial rod which is ensheathed by an inner circular and several bundles of longitudinal layers of muscles, which in turn are surrounded



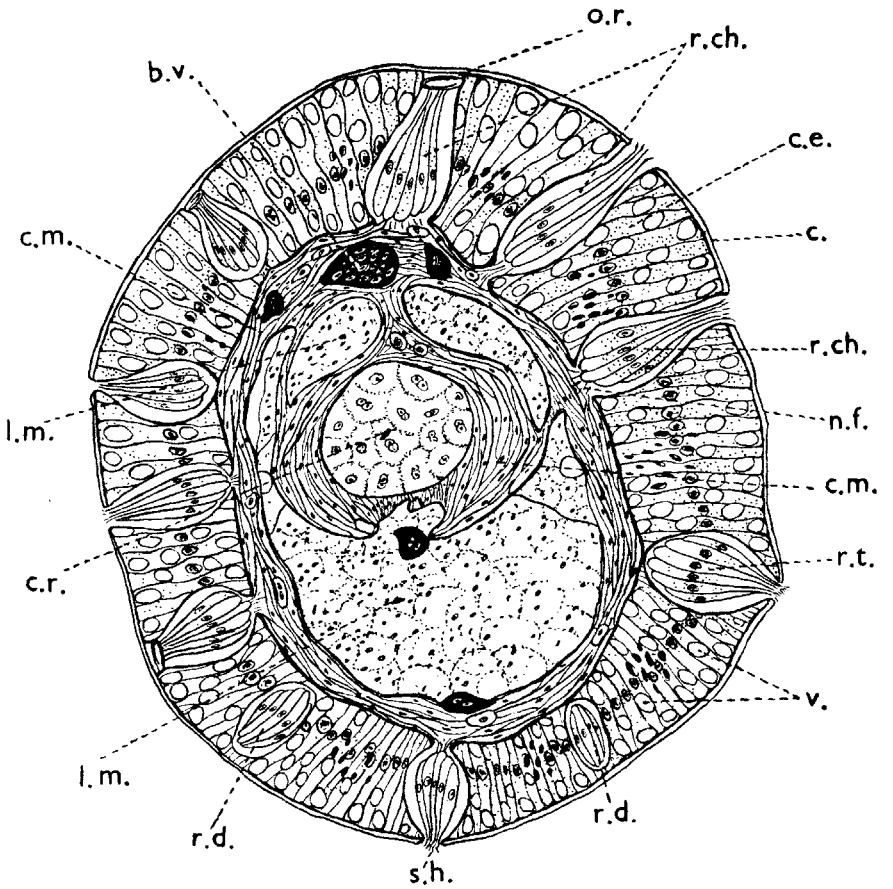
TEXT-FIG. 4.—*Glyptosternum labiatum* (Blyth). Transverse section through the integument. (Reproduction of Hora's Text-figure).

b.v., blood-vessel; *c.*, clavate cell; *c.t.*, connective tissue; *e.c.*, small epithelial cells; *g.c.*, gland cell; *p.*, pigment.

by a second circular layer of muscles. Around this is present a layer of radially arranged epidermal cells which has a thin cuticular covering. The epidermal cells are highly vacuolated, each cell having a finely granular protoplasm and a centrally placed spherical nucleus. In between the epidermal cells there are a large number of receptors which are modified epidermal cells. It is apparent that the barbels are highly sensory and the vacuoles within the epidermal cells add to the turgidity of the barbels to enable them to perform the adhesive function efficiently.

(iv) *The Region of the Branchiostegial Rays* (Text-figs. 1, *b.r.* and 6*a*, 6*b*).

The integument covering the ventral surface of the branchiostegial rays is obliquely fluted, and grooves and ridges run parallel to the branchiostegial rays, and anteriorly meet in the mid-ventral region. A free hand section (Text-fig. 6*a*) shows the true nature of the integument of this part, as also the nature of the spines on the ridges. The epidermis consists of a well-formed layer of columnar epithelial cells. Each cell has finely granular cytoplasm and an oval nucleus at the base. Next to the epidermal layer, there are several tiers of irregularly scattered cells (the formative cells) which do not form a layer. Both the ridges and the grooves have a cuticular covering which is modified into number of short stout spines over the ridges. The grooves are devoid of spines. A few flask-shaped tango-receptors are also present in this region.



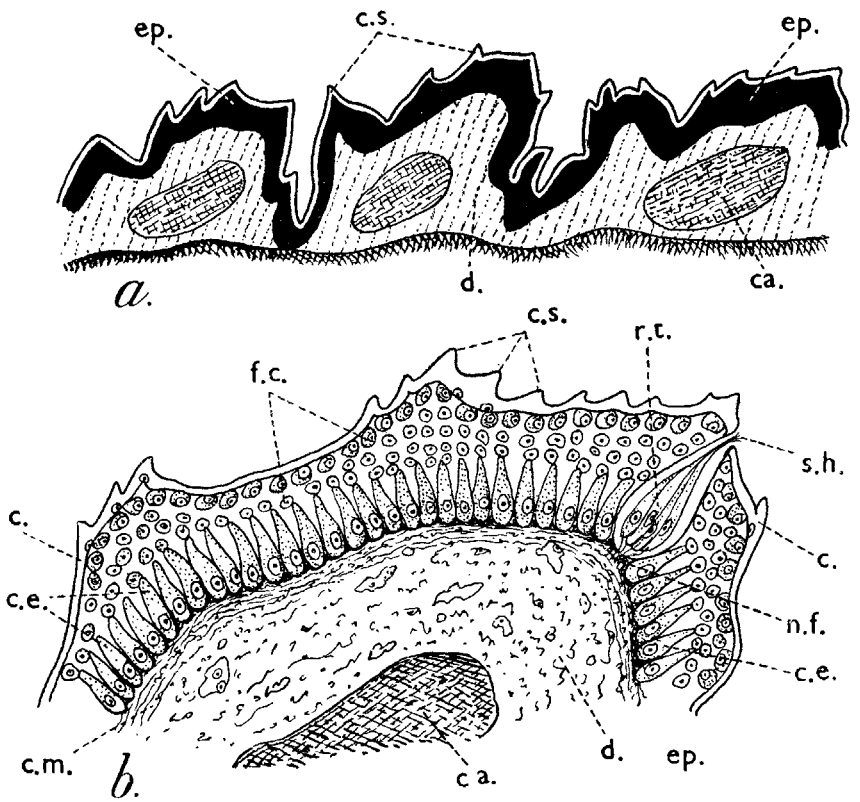
TEXT-FIG. 5.—*Glyptothorax telchitta* (Hamilton). Transverse section through a maxillary barbel. *b.v.*, blood-vessel; *c.*, cuticle; *c.e.*, columnar epithelial cells; *c.m.*, circular muscle layer; *c.r.*, cartilaginous rod; *l.m.*, longitudinal muscle layer; *n.f.*, nerve fibre; *o.r.*, opening of the receptor ; *r.ch.*, chemo-receptor; *r.d.*, developing receptor; *r.t.*, tango-receptor; *s.h.*, sensory hair; *v.* vacuoles.

(v) *The Thoracic Adhesive Apparatus* (Text-figs. 1, *a.p.*, 7 and 8).

Like many other hill-stream fishes, the under surface, particularly the ventral thoracic region of this form is flattened so as to come into close contact with the substratum on which the fish rests. The generic name *Glyptothorax* is indicative of this feature of the genus.

The integument of the ventral region, between the bases of the two pectoral fins, has a distinctly marked rhomboidal area which is longitudinally pliated and presents regular corrugations (Text-fig. 1, *a.p.*). A free hand section of a piece of skin from this region (Text-fig. 7) shows longitudinal ridges and alternating grooves. The ridges appear in the form of plates, and are seen bristling with long closely-set spines, the apices of the spines are curved and are all directed backwards. The grooves are without any spines and are smooth.

A microtome section (Text-fig. 8) reveals that while both the dermis and the epidermis form the entire adhesive apparatus (ridges and grooves), it is really the epidermis and its derivatives which are principally concerned with the function of adhesion.



TEXT-FIG. 6.—*Glyptothorax telchitta* (Hamilton). Structure of the branchiostegial region.

a. Free-hand section through the region of the branchiostegial rays; *b*. Microtome section of the same.

c.a., cartilage; *c.e.*, columnar epithelial cells; *c.m.*, circular muscle layer; *c.s.*, cuticular spines; *d.*, *dermis*; *ep.*, epidermis; *f.c.*, formative cells in tiers; *n.f.*, nerve fibre; *r.t.*, tango-receptor; *s.h.*, sensory hair.

The adhesive pad is made up, from inside out, of the following layers:—

(*a*) The epidermis,
(*b*) Formative cells,
(*c*) Beak-shaped cells,
(*d*) Cuticle, and cuticular spines.

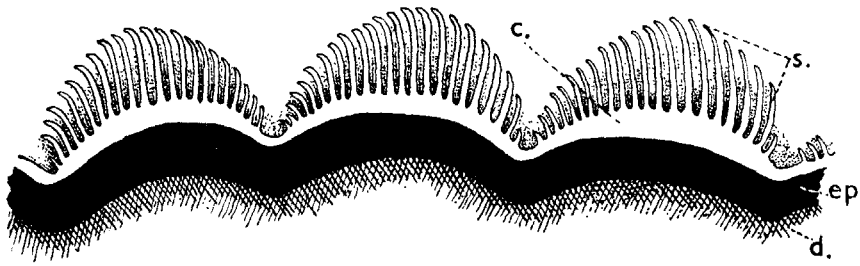
(*a*) *The epidermis.*

Next to the dermis is the epidermis, a layer of slender, closely packed, columnar epithelial cells. The cytoplasm is uniformly granular and an oval nucleus is placed in the central region of each cell. The cells within this layer are in an active state of mitotic division, and as a result of this division a large number of cells arise from the epidermis which remain scattered towards the outer border of the epidermal layer.

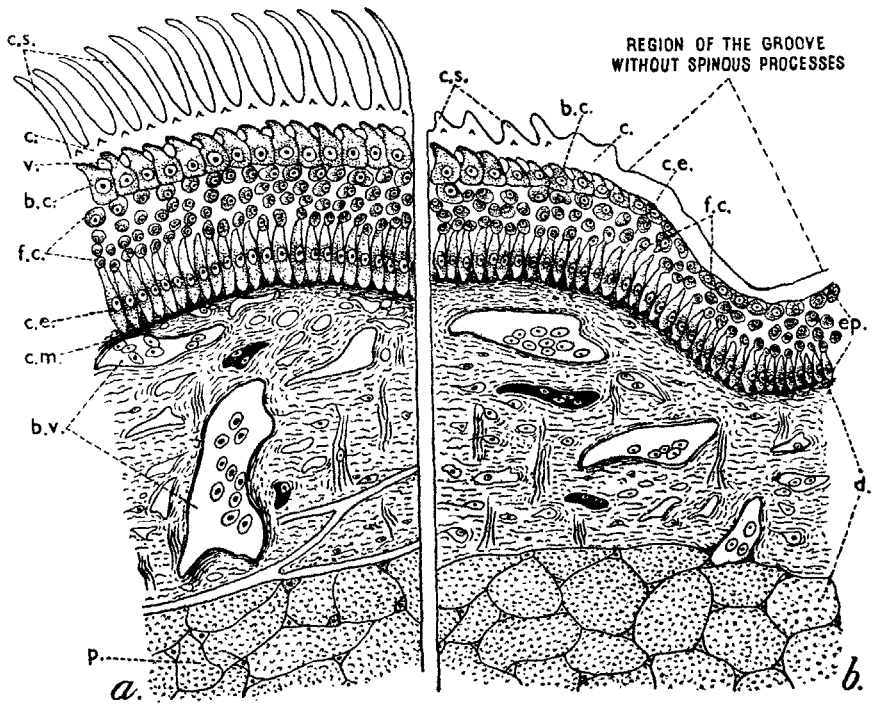
(*b*) *Formative cells.*

Several tiers of cells, derived from the epidermis, are present next to the epidermis. They are well-formed, oval cells, each having finely granular cytoplasm

and a centrally placed nucleus. They never combine to form a layer and are loosely scattered. They seem to behave like wandering cells. It is worth noticing that the cells nearer the epidermal layer are smaller, each cell bearing a small central nucleus, while cells further away, *i.e.*, cells in the outer tiers are large, and each



TEXT-FIG. 7.—*Glyptothorax telchitta* (Hamilton). Free-hand section of the adhesive pad, cut transversally to the skin plaits.
c., cuticle; *d.*, dermis; *ep.*, epidermis; *s.*, spines.



TEXT-FIG. 8.—*Glyptothorax telchitta* (Hamilton). Transverse section of a ridged portion of the 'adhesive pad'.
a. Central part of the ridge; b. Edge of the ridge.
c. grooved part. *b.c.*, beak-shaped cells; *b.v.*, blood-vessels; *c.*, cuticle; *c.e.*, columnar epithelial cells; *c.m.*, circular muscle layer; *c.s.*, cuticular spine; *d.*, dermis; *ep.*, epidermis; *f.c.*, formative cells; *p.*, parenchyma; *v.*, vacuole.

bears a large clear nucleus, with a well formed central nucleolus. These cells are being designated here as formative cells.

(c) *Beak-shaped cells.*

Cells of the outermost tier form a single row of squarish cells, each cell giving out at its free outer end a beak-shaped protoplasmic process. The cytoplasm within the main cell, as also in the process, is uniformly granular. Each cell has a centrally placed large clear nucleus, with a prominent central nucleolus. It is worthy of note that all the protoplasmic processes in this layer are directed one way, *i.e.*, towards the posterior side of the fish. In between the consecutive processes there are alternating vesicular spaces.

(d) *Cuticle and cuticular spines.*

Immediately next to the protoplasmic processes is a thin transparent, non-cellular covering layer, the cuticle, from which arise long spines. Both the spines and the cuticle take a mild stain. All the spines, like the protoplasmic processes of the underlying layer, are directed backwards. A careful counting reveals that there are as many spines in the section, as the underlying protoplasmic processes. The adhesive apparatus region is altogether devoid of receptors.

Discussion.

Hora (1922, pp. 47–58) described a number of species in various stages of adaptations to swift water current and showed how the development of spines is correlated with the intensity of the current. He made a comparative study of similar adhesive apparata in the hill-stream fishes of the order Cyprinoidea.

His description and figures of this part in *Bhavania annandalei* indicate that the material handled by him was not in a good state of preservation to enable him to determine the real epidermal layer. What he calls the basal epithelial cells is the epidermal layer proper. Most of the histological structures shown by him in his Text-fig. 19 on page 57, reproduced here as Text-fig. 9, are very similar to those figured in *G. telchitta* (Text-fig. 8) and his sketches interpreted on the lines of my findings become self-explanatory. Similar confusion exists about structures seen in *Garra*, where a superficial epidermal layer is described. The basal region, of which the cells are not well marked, is the real epidermis.

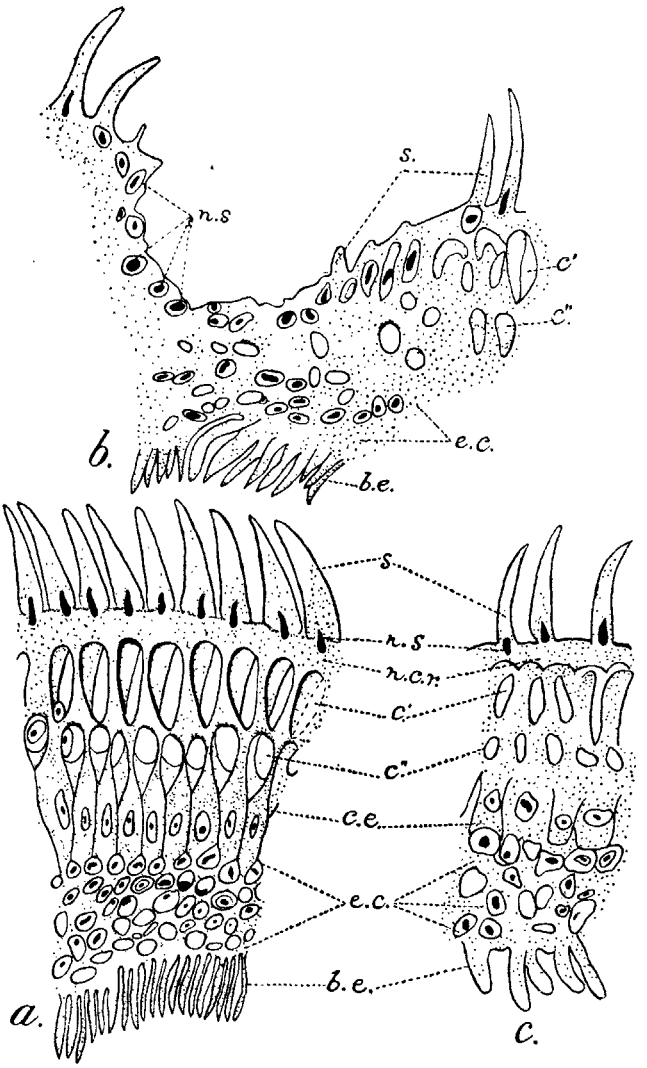
Among the Siluroidea, Hora studied the conditions seen in several species under the genus *Glyptosternum*. In *Glyptosternum labiatum* (Text-fig. 4), he missed locating the epidermis. Several layers of cells put together are labelled by him as epithelial cells. This figure studied on the lines suggested above will help to interpret rightly all the structures figured by him.

The conditions described by him in *Glyptothorax dorsalis*, page 55, are noteworthy. It is a resident of sluggish and muddy streams of the Manipur Valley, the spines, as a natural consequence, are small, and the spinous layer as a whole is not well developed. Here too the basal layer which is described by him as highly vacuolated is in reality the epidermis.

In *Glyptothorax madraspatanus*, the adhesive tissue is described by him as more advanced (p. 55), but the reasons put forward by him for this conclusion are not sound. He says, 'the adhesive tissue is more advanced in so far as the cell limits are not distinguished.' This condition is due to poor state of preservation of the tissue rather than to any kind of advancement in structure. Hora's own statements at two different places regarding the general make up of the adhesive apparatus tissue, where he says that the cell limits are not distinguishable, and that in the

basal epithelial layers he was not able to find any nuclei, support my assumption about the poor state of preservation of the materials handled by him.

In *Glyptothorax* sp., where the greatest specialization in the structure of the adhesive tissue within the genus is reached, Hora's interpretation of epidermis and its derivatives is based on an erroneous ground. His figure 19*a* of *Glyptothorax saisii* giving three sketches (Text-fig. 9) of the adhesive apparatus further confirms my findings. The real epidermal layer, recognized here too as basal layer has been given the least attention and it is stated to consist of cells without nuclei.



TEXT-FIG. 9.—*Glyptothorax* sp. Minute structure of the adhesive apparatus on the under surface. (Reproduction of Hora's Text-figure.)

a. transverse section through a portion of the ridge; *b*. transverse section through a portion of the groove; *c*. horizontal section through a portion of the ridge.

b.e., basal epithelial cells; *c'*., first row of cavities; *c''*., second row of cavities; *c.e.*, columnar epithelium; *e.c.*, small rounded epithelial cells; *n.c.r.*, non-cellular region; *n.s.*, nucleus of the spine; *s.*, spine.

Much more attention has been paid to the cells derived from the epidermis than to the real epidermis. Changes noticed by Hora, as to the structural differences between ridges and grooves are very similar to those observed by me in *Glyptothorax telchitta*.

Hora's findings regarding the general make up of the adhesive apparatus in various forms are very helpful. While his sketches showing the histological details are very useful, his interpretation of the different units that jointly form the adhesive apparatus, needs revision.

Wu and Liu's contribution on the structure of the adhesive apparatus of *Glyptosternum* (= *Glyptothorax*) (*Sinensia*, 1940) instead of adding to our knowledge something fresh, has added to the confusion of ideas about the structure and function of the apparatus. Their statement that the histological nature of it is practically unknown shows that they were completely ignorant of Hora's detailed investigations of this and similar other structures.

The entire epidermis and its derivatives are described by them as stratum germinativum, which, according to them, constitutes most of the epidermis, and consists of 8 to 10 cells layers. These layers are further described and labelled by them in their figures in the following manner:—

(*a*) The deepest layer composed of elongated pyramidal cells is the basal layer.

(*b*) It is overlapped by 3-4 layers of elongated spindle-shaped cells, which do not differ much from the cells of the basal layer.

(*c*) Passing towards the surface, the cells are irregular polyhedral in shape, small at first, but larger in the succeeding layers. Some 4 to 5 rows of such cells are shown in the figure.

(*d*) The most superficial layer isnamed as stratum corneum, and the cells in this layer are separated from each other, by intercellular spaces, which in turn are traversed by intercellular bridges.

At another place the layer stratum corneum is described by them as consisting of a single layer of cells. Owing to the disappearance of the intercellular spaces here the boundaries of cells are more or less in obscurity, the distinctive feature of this layer is that the free surface of its cells is fused, thickened and keratinized. That practically every cell at the ridged portion bears a spinule, seems to be of interest.

They have further described that the spinule, stained the same as the free border, is found to be a direct protrusion of the latter. It is really a modified part of the cell wall, a blind tube filled with cytoplasm.

At the base of each spinule is shown by them a clear pear-shaped space within which is figured an acute oval structure. They interpret the clear space as the position formerly occupied by the nucleus and the acute oval structure as the nucleolus, though they admit that its enormous size, somewhat renders this designation less convincing. They admit by saying 'We are not at present in possession of a definite idea concerning the real nature of this structure, but it is our belief that whatever this structure may be, it seems to be intimately correlated with the cornification of the stratum corneum.'

As to the function of this structure, it is *regarded by them less adhesive than protective*.[1] The deficiency of the *goblet cells* apart from the cornification and spinule formation of the free border of the epidermis led them to believe so.

They further believe that the chest of this fish is liable to friction when it perches, as it used to be on rocks or stones, and there is much need of a structure to protect this scaleless region against mechanical influence. Although

[1] Italics are mine.

they conclude by saying that the spinules might act as numerous small pegs to help the fish resting more steadily upon the substratum under swift currents, they feel at the same time that *this apparatus cannot subjectively effect* adhesion as performed by the mouth of Cyclostomata, sucking disc of *Lepidogaster*, paired fins of *Sinogastromyzon* and ventral fins of *Gobius* seems beyond all doubt. It will be readily admitted that the adhesive disc of *Glyptothorax* does not function as a sucking disc of the fishes referred to by Wu and Liu, but acts as a frictional device for increasing adhesion to the substratum.

Although Wu and Liu (1940) adopted very elaborate micro-technique, they were not able to ascertain rightly the histological details of the different parts of the disc in their preparation. Their work unfortunately sheds very little light on the point. It is apparent that their observations on some of the points are mistaken, while those of Hora are correct. Unfortunately their description and diagrams of the adhesive disc are based on an incomplete appreciation of the details of its structure and are therefore not very helpful.

Probable origin of adhesive pad.

(Text-fig. 10.)

A close study of the successive stages of series of microtome sections reveals the way different elements that form the adhesive disc are developed from a simple columnar epithelium. It is the perching habit which tends to bring about mechanical devices that help the fish to maintain its position against strong currents.

In the beginning there is a simple epidermis consisting of a single layer of columnar epithelium, with a thin covering of cuticle. Cuticle is the layer exposed to great stress and strain, and it must therefore exert both physical and mechanical means to gain fixed points for maintaining a position. Cuticle gets modified into large spines, which act as pegs. It gets torn at times and is very soon replaced by fresh cuticular covering. This regeneration of cuticle is made possible by the underlying epidermal cells and its derivatives.

Text-figure 8 shows how the epidermal cells get modified to form the cuticular spines, and the way cuticular layer regenerates.

Epidermis consists of a single layer of columnar epithelial cells, and there is a thin layer of cuticle (Text-fig. 10*a*). Epidermal cells are in active state of mitotic division and give rise to formative cells, *i.e.*, cells which ultimately form the cuticle. The first series of formative cells form a layer beneath the cuticle, and fresh cells that arise from the epidermis remain in reserve in several tiers (Text-fig. 10 *b*, *c*, *d*, *e*) those close to the epidermal cells are the smallest of the series.

Perching habit makes the cuticle project beyond the surface level, and each projection is a cuticular spine. This projection is initiated by the underlying layer of cells, each cell giving out a protoplasmic process which give the cells in this layer beak-shaped appearance. Text-fig. 10*f* shows the formation of small spinules, and at the base of each spinule there is the projecting protoplasmic process of the underlying cell.

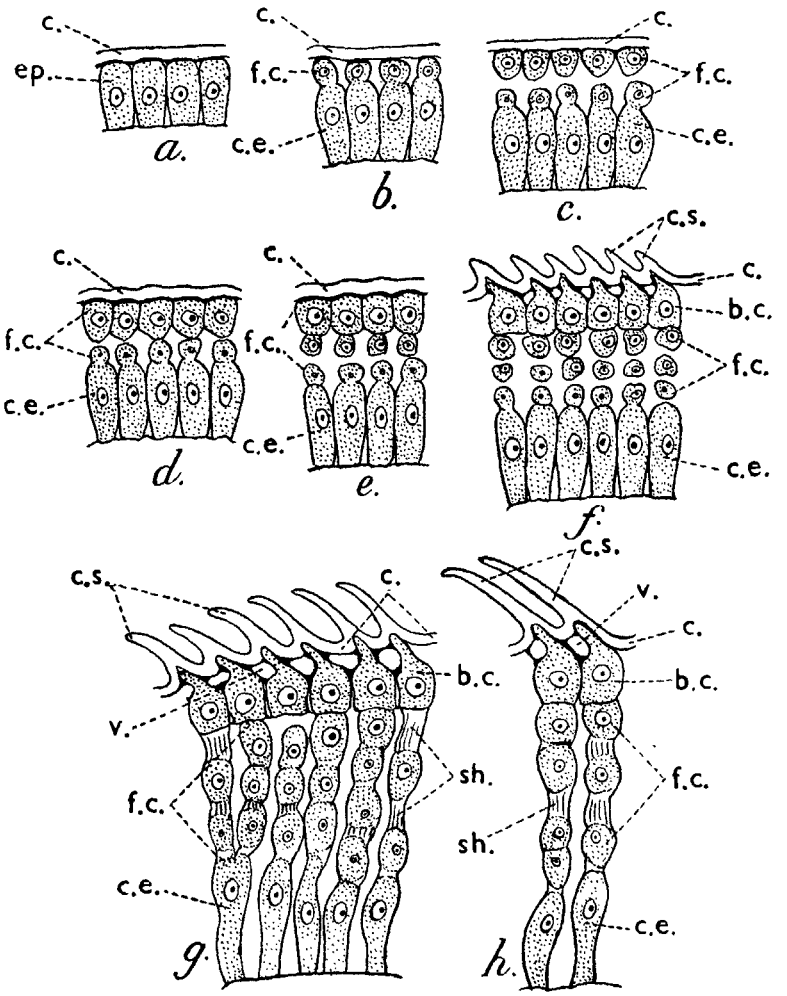
As a result of mitotic division of the epidermal cells there is a constant supply of formative cells, which at times remain ensheathed in a chain from the place of their origin to underneath the cuticle (Text-fig. 10 *g*, *h*).

It has been noticed in the preparations that at places, where the cuticular layer gets torn off, the protoplasmic processes of cells of the underlying layer take the place of cuticular spines till fresh cuticle is regenerated. Wu and Liu's illustrations appear to have been taken from preparations where cuticular layer is not present, and spinules are only the protoplasmic processes of the underlying cell layer.

Function of the different parts.

The anterior and posterior lips, the maxillary barbels, the region of the branchiostegial rays and the adhesive pad, all perform an adhesive function. The papillated regions of the two lips perform it by adpression, and the region of the branchiostegial rays by means of the cuticular spines. All the three regions have a relatively less adhesive power than that of the specialized adhesive disc.

General structure of the adhesive disc, total absence of receptors in this region, the long cuticular spines, and the way cuticle is regenerated, leave no doubt in my mind as to its being adhesive.



Text-fig. 10.—*Glyptothorax telchitta* (Hamilton). Developing stages of the 'adhesive pad'.

a. Stage with single layer of columnar epithelium; *b*. Stage showing the birth of the formative cells from the epithelium; *c*. Stage showing the birth of a reserve layer of formative cells; *d*. Stage showing the reserve layer of formative cells fusing to form the cuticle; *e*. Stage showing the formative cells joined with the first tier of formative cells and the birth of another layer; *f*. Stage showing formation of small spinules; *g*. & *h*. Stages showing the formative cells ensheathed in chains.

b.c., beak-shaped cells; *c.*, cuticle; *c.e.*, columnar epithelial cells; *c.s.*, cuticular spines; *ep.*, epidermis; *f.c.*, formative cells; *sh.*, sheath; *v.*, vacuole.

Wu and Liu's view that adhesive apparatus cannot subjectively effect adhesion and that the spinules are less adhesive than protective is at best a conjecture without much observational or experimental evidence.

Long spines, all directed one way, behave like pegs, and these devices, helped by large number of teeth on the two jaws, all combined, form very efficient adhesive organs.

ABSTRACT.

This paper, part I of the series, deals with the epidermal organs which serve adhesive function in a small catfish *Glyptothorax telchitta* found in fast flowing streams of the Rihand River, Mirzapore, U.P. Due to the resistance offered by the fish against strong water currents, a number of epidermal adhesive devices are developed in it which help the fish to maintain a more or less stationary position in fast running waters.

These are:

(*a*) *The Rostral hood, i.e.*, the region in front of the mouth, which is secondarily formed and covers the anterior lip. It is in the form of a pad and is profusely papillated subserving an adhesive function.

(*b*) *The posterior lip* region is also papillated and these papillae are longer than those of the rostral hood.

(*c*) A pair of *maxillary barbels*—also help in the process of adhesion.

A large number of Receptors are present on the Rostral hood, the posterior lip, and on the maxillary barbels.

(*d*) The region of the *Branchiostegial rays* has a grooved integument which bears short stout spines.

(*e*) In the *Thoracic adhesive apparatus* the integument of the ventral chest region has a marked rhomboidal area which is longitudinally pliated. The ridges are provided with long curved cuticular spines which help the fish to stick to the substratum. This region is devoid of receptors.

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