THE INTEGUMENT, EXOSKELETON AND CUTANEOUS SENSE ORGANS OF *SISOR RABDOPHORUS* HAMILTON

by C. L. Mahajan, *Department of Zoology, University of Rajasthan, Jaipur*

(Communicated by L. S. Ramaswami, F.N.I.)

(*Received February 28, 1966*)

Detailed anatomical and histological studies of the integument, exoskeleton and cutaneous sense organs of *Sisor rabdophorus*, a peculiarly modified Indian catfish, reveal that these structures are admirably adapted for sluggish bottom life, *e.g.* it was found that taste buds are distributed all over the integument, including the upper caudal filament, as a compensation for reduced eyesight. Similarly, peculiar epidermal specializations named here as 'cornified tubercles' were discovered and apparently have a protective function. This is fortified by the extensive dermal ossifications on the back and around the lateral-line. Certain interesting similarities of club cells in the epidermis of *Sisor* with those of sac cells in the South American catfish families Loricariidae and Callichthyidae have been pointed out.

Introduction

Bhatti (1938) in a contribution to our knowledge of the integument and dermal skeleton of Siluroidea (families Loricariidae, Callichthyidae, Doradidae and Bagridae) reviewed the previous literature on the subject. Subsequently a few papers on the integument of siluroid fishes have appeared with particular reference to cutaneous sense organs. Sato (1937)* reported the presence of taste buds on the barbels of *Plotosus anguillaris* and later the same author in a series of papers (1949, 1955, 1956, 1962) dealt with various aspects of the study of pit organs in *Parasilurus asotus* along with a number of other fishes. Bhatti (1952) studied the cutaneous sense organs of *Rita rita*; Sato and Kapoor (1957) made some observations on the barbels of a few Japanese and Indian fishes including two catfishes, viz. *Callichrous bimaculatus* (Hamilton) and *Heteropneustes fossilis* Bloch.

Literature on cutaneous sense organs of fishes in general has been reviewed by Moore (1950) and more recently by Hasler (1957). It is significant to note that no member of the family Sisoridae has been investigated from this aspect. A few references are, however, available on the adhesive apparatus (not found in *Sisor*) formed by integumentary modifications in some members of the family such as those of Hora (1922) on *Glyptothorax* spp. and

* This paper was not referred to by Bhatti (1938).

Glyptosternum labiatum, Bhatia (1950) on *Glyptothorax telchitta* and Saxena (1961) on *Pseudecheneis sulcatus*.

Material and Methods

In the present investigation a study of the general histology of the skin from various parts of the body (including the barbels and the fins) was made by studying sections 5–10 μ in thickness stained with iron haematoxylin—Orange G or Mallory's triple stains. Serial sections of the entire fish (10–20 μ thick) proved very helpful in studying the distribution of various integumentary modifications.

The exoskeleton and its relationship with endoskeleton was studied by preparing alizarin transparencies and their histological nature was examined by studying serial sections of the decalcified fish.

Observations

The Integument (Pl. I)

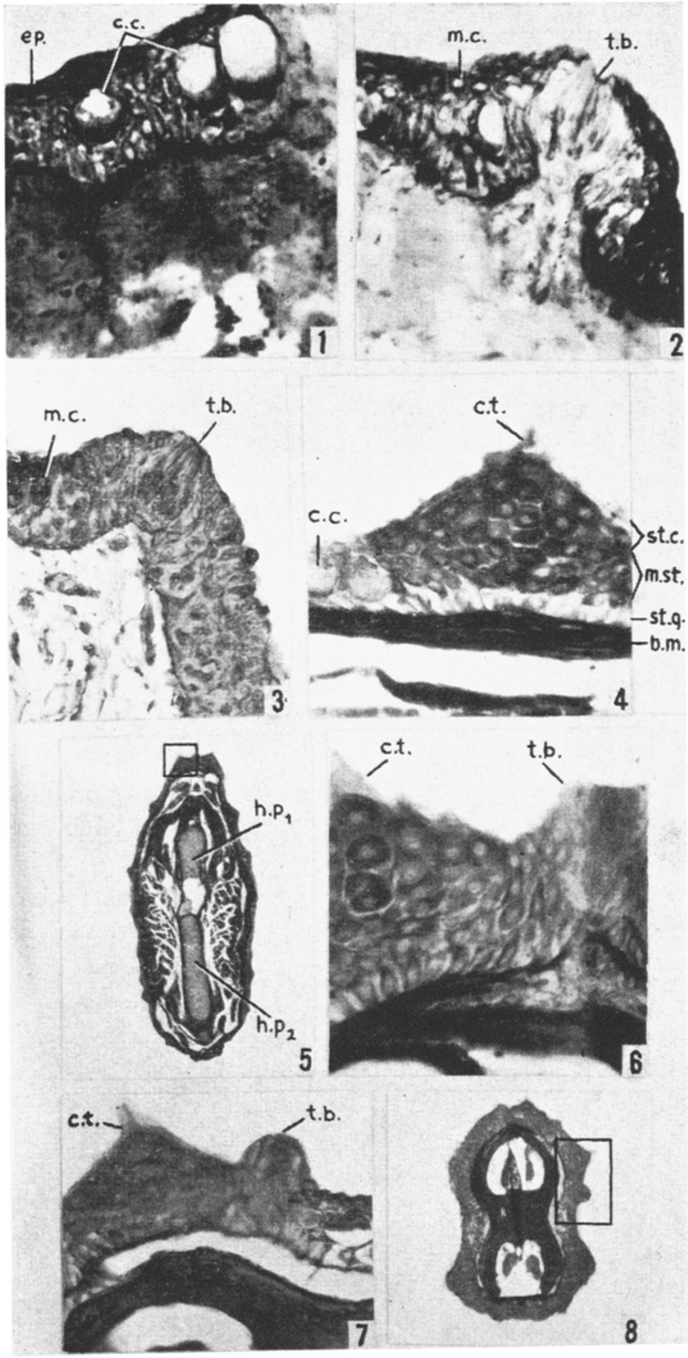
A detailed histological examination of the integument of *Sisor rabdophorus* revealed that while conforming in general to the basic siluroid pattern (Bhatti 1938) it shows certain peculiarities and specializations which may be correlated with the sluggish bottom life of this species. These are recorded below:

(i) *Cornified tubercles* (Pl. I, fig. 4): These are the most characteristic structures found in *Sisor* and, so far as I am aware, have not been described in any siluroid so far. Each typical tubercle is formed by a group of polygonal epidermal cells arranged in the form of a pyramid with the stratum germinativum (*st.g.*) as the base. The central row of the pyramid may be 6–8 cells deep. Each of these cells has a distinct rounded nucleus. The outermost layer of this pyramid is formed by cells, each of which is produced into a cornified conical apex and has a flattened base with a distinct nucleus of the same type as the other cells below.

The outermost layer, it appears, is periodically shed off and replaced by the one immediately below. Each cell of the new layer develops a conical horny apex similar to that of its predecessor. In the serial sections, recently

---

Figs. 1–8 (*b.m.*, basement membrane; *c.c.*, clevate cells; *c.t.*, cornified tubercle; *ep.*, epidermis; $h.p_1$, upper hypural; $h.p_2$, lower hypural; *m.c.*, mucous cell; *m.st.*, middle stratum; *st.c.*, stratum corneum; *st.g.*, stratum germinativum; *t.b.*, taste bud). 1, a c.s. through the skin of the dorsal side of the trunk region. ×100. 2, a c.s. through the skin of the ventral side of the trunk region. ×100. 3, a c.s. through the buccal lining. ×100. 4, a c.s. through a typical cornified tubercle. ×450. 5, a t.s. through the posterior part of the caudal peduncle. ×35. 6, enlarged view of the area marked in a square in photomicrograph 5. ×450. 7, an enlarged view of the area marked in a rectangle in photomicrograph 8. ×450. 8, a t.s. through the upper caudal filament. ×35.



FIGS. 1–8.

dead cells were seen with conspicuous nuclei which took dark stain. In the area of the tubercle which may be 100–200 μ in diameter, there are neither mucous cells nor clevate cells. As if to make up for this, the epidermal area immediately surrounding the cornified tubercle has invariably a large number of clevate cells although the number of mucous cells does not appear to increase appreciably. These 'cornified tubercles' present the typical structure described above on the dorsal and lateral sides of the body. They are present on all the fins, specially on both sides of the fin rays of the dorsal and caudal fins. On the ventral side, their outer layer is flat and cornified but is not produced into conical apices.

In general, the number of these tubercles appears to be inversely proportional to the number of taste buds. Thus, while they are numerous and of a typical form on the dorsal side of the head, they are almost non-existent on the ventral side where taste buds abound. The mandibular barbels and the barblets which are studded with taste buds do not have even a single representative of these structures. The maxillary barbel, on the other hand, has 'cornified tubercles' on its dorsal and outer margins while on the inner and ventral side the taste buds are more common. On the lateral side of the head both the 'cornified tubercles' and taste buds are met with. In general, the cornified tubercles are more pronounced in the younger than in the older specimens; dorsal than on the ventral side of the body.

(ii) *Taste buds:* The taste buds in *Sisor* are similar in structure to those described in other siluroids (Bhatti 1952) but their extent and distribution are interesting and can be correlated with sluggish bottom life. They are present all over the body and fins (except perhaps the dorsal fin where none was observed), including the upper caudal filament (Pl. I, Figs. 5–8). As a rule they are larger in size and more numerous anteriorly than posteriorly on the ventral side of the body than on the dorsal side. Thus they are found in large numbers on the ventral side of the head as described in the preceding paragraph.

(iii) The *club cells:* The club cells (clevate or giant cells) of *Sisor* (Pl. I, Fig. 1, *c.c.*) differ in three respects when compared to those described in other catfishes such as *Amiurus* (Wright 1884) and *Rita rita* (Bhatti, H. K., 1938; Bhatti, I. H., 1952) in that: (*a*) they are always situated in a single row, (*b*) their contents are always homogeneous and concentrated towards the base leaving the upper half as a clear space and (*c*) that the nucleus is basal. This is in great contrast to the findings of Bhatti (1938) in *Rita rita* where he observed that the nucleus is 'always situated in the centre of the cell' and also that 'in large club cells the contents become vacuolated' and that 'the club cells lie in three or four rows'. These findings of Bhatti (1938) have later been confirmed by Bhatti (1952). In the basal situation of the nucleus and in being arranged in a single layer occupying almost the whole length of epidermis, club cells of *Sisor* appear to resemble the 'sac cells' described by Bhatti (1938) in the family Loricariidae of South America.

(iv) *Mucous cells:* The mucous cells in *Sisor* are surprisingly inconspicuous throughout the outer skin, being very few in number and rarely attaining a size larger than the ordinary epidermal cells (Pl. I, fig. 2, *m.c.*). Only in pharyngeal lining do they become numerous and attain the usual size and form.

The Exoskeleton (Figs. 1–7)

The exoskeleton in *Sisor rabdophorus* consists of a series of bony plates or scutes on the back and the lateral-line ossicles. The histological nature of these scutes and ossicles is the same as the rest of the endoskeleton.

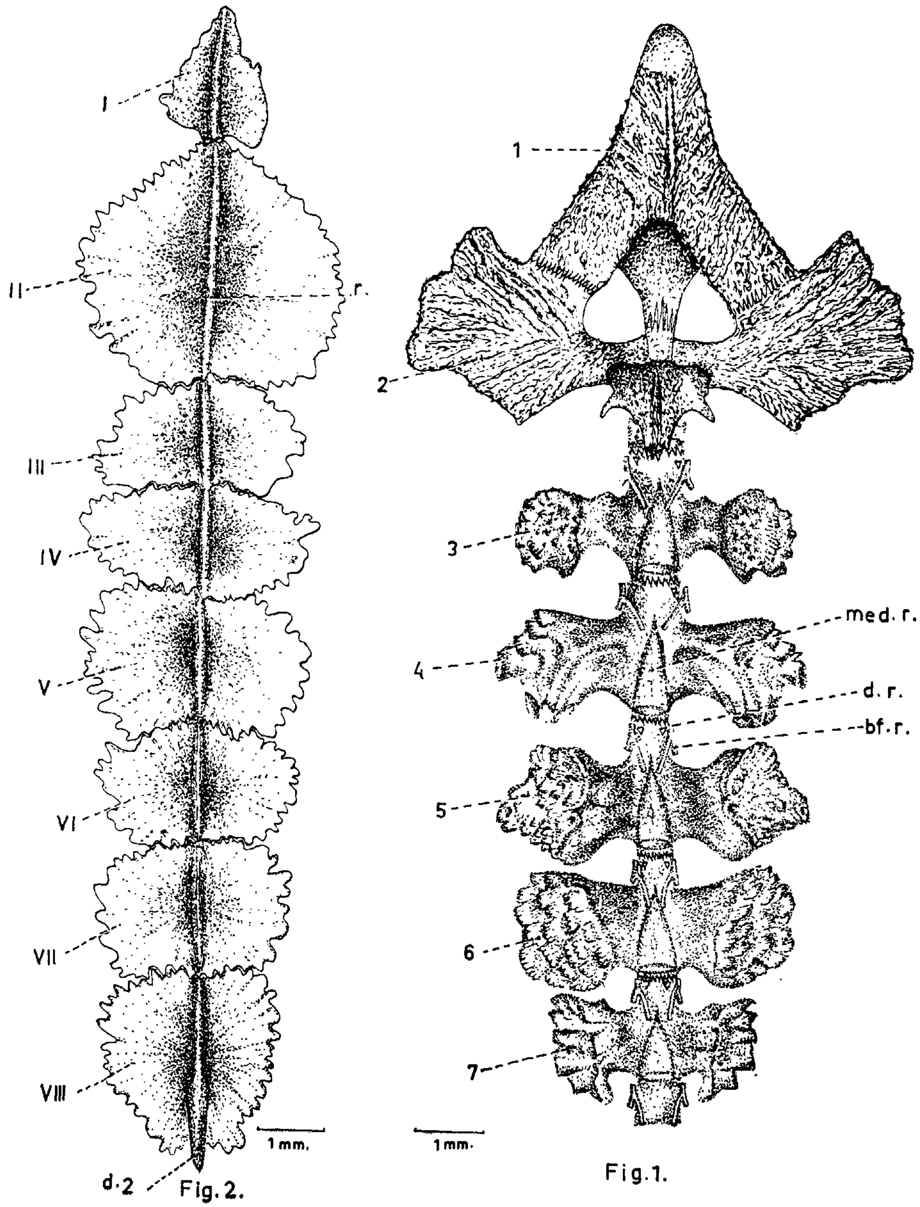
The *bony plates:* The bony plates on the back can be distinguished into two kinds:

(i) The bony plates associated with the dorsal fin.
(ii) The bony plates behind the dorsal fin.

The bony plates associated with the dorsal fin (Fig. 1) are seven on each side of the dorsal fin and are fused with the respective basal supports of the dorsal fin. The fusion takes place at the point where proximal and median radials meet and are themselves fused indistinguishably. The first two plates (1 and 2) are much larger than the rest. The first is connected with a part of the sound-producing apparatus (Mahajan 1963) while the second is the broadest of all. The rest five (3–7) are more or less similar. All of them bear prominent ridges and tubercles on their dorsal surface. The cornified tubercles of the integument described above are most often seen on these tubercles and ridges.

Bony plates behind the dorsal fin (Fig. 2) vary in number from six to ten. Each bony piece has a prominent median ridge (*r.*). The first (I) is the smallest in the series, the second is the biggest (II), while the last (III) bears a prominent spine-like backward projection (*d.2*) which has often been compared with the remnant of the second dorsal fin. The small skin flap situated behind it has a conspicuous layer of adipose tissue. These bony plates are not fused with the underlying neural spines. Dorsally, each plate bears prominent ridges and tubercles which have the same relationship as those of the first series with the overlying skin.

The *lateral-line ossicles:* The lateral-line of *Sisor* in the trunk and tail region is enclosed by a series of ossicles formed by dermal ossifications comparable to the scales of cyprinoid fishes. They are more or less constant in number and vary within narrow limits, *e.g.* in ten alizarin transparencies examined, the number of ossicles varied between 72 and 76. These ossicles greatly vary in shape because the extent and degree of ossification increases



FIGS. 1 and 2 (*bf.r.*, base of the fin ray; *d.r.*, distal radial; *d.2*, spine representing second fin ray; *med.r.*, medial radial; *r.*, ridge; 1–7, bony plates associated with the dorsal fin; I–VIII, bony plates behind the dorsal fin): 1, the bony plates associated with the dorsal fin (dorsal view). 2, the bony plates behind the dorsal fin (dorsal view).

in general from before backwards till it is maximum in the middle region. More posteriorly, in the caudal region, ossicles assume a regular elongated form. Smaller ossicles were generally found interspersed between the bigger ones. As expected the degree of ossification increases with age, thus each individual ossicle grows in size but the number of ossicles remain the same.

The main types of ossicles met with in *Sisor rabdophorus* are shown in Figs. 3–7. In Fig. 3 are shown the anteriormost ossicles just behind the

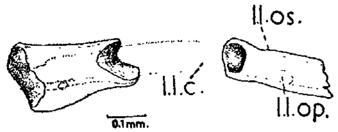


Fig. 3.

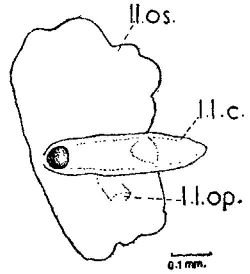


Fig 5.

Fig. 4.

FIGS. 3–5 (*l.l.c.*, lateral line canal; *l.l.op.*, opening of the lateral line canal; *l.l.os.*, lateral line ossicle). Representative shapes of the lateral-line ossicles from anterior to posterior side. 3 shows those of the anteriormost region. 4, 5 represent those slightly posterior.

head region. These are simple tubular structures. Figs. 4 and 5 show ossicles of a more posterior region where the ossification is gradually extending both on the dorsal and ventral sides. Fig. 6 shows one of the ossicles from the middle region of the body which may be considered as a representative of the

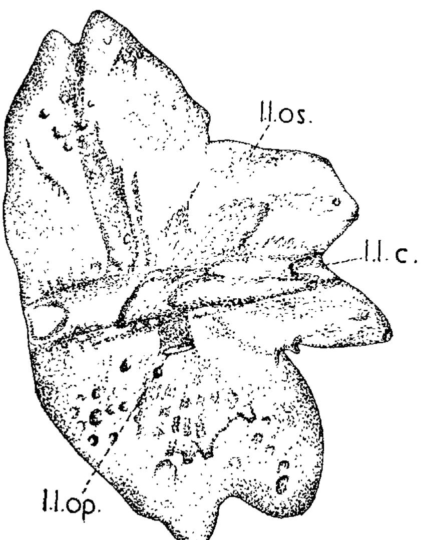


Fig. 6.

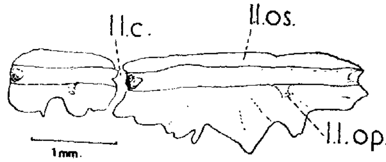


Fig. 7.

FIGS. 6 and 7 (*l.l.c.*, lateral line canal; *l.l.op.*, opening of the lateral line canal; *l.l.os.*, lateral-line ossicle): 6 shows a typical ossicle from the mid-trunk region. 7 represents those on the posterior caudal region.

largest of them. In the latter case, not only are the wing-like processes greatly extended both on the dorsal and ventral sides but they also bear a lot of superficial ossification in the form of ridges or protuberances on their outer surface. Fig. 7 shows the ossicles seen in the posterior caudal region, *i.e.* from 24th vertebra backward. They are elongated and assume a more definite shape although still irregular in outline. In this region, ossicles of smaller length may alternate with the longer ones and in this manner 3–5 ossicles may be found on two successive vertebrae together. Thus the lateral-line on the last ten or eleven vertebrae (23–34) is enclosed by 32–35 ossicles.

Discussion

> 'It is now evident that the integument, considered as a whole with its accessory structures, serves many purposes in fishes. The most obvious role is protection. The skin covers the body and protects the deeper tissues against injuries and infections. The dermal skeleton performs the same function... It (the integument) is a receptor of stimuli. It is a seat of many organs with a special function. It is the principal organ of contact with the outer world.' Van Oosten, 1957.

With the above premise and in the light of the observations recorded above, it will be seen that the integument and dermal skeleton of *Sisor rabdophorus* is admirably adapted to its particular mode of life and the environment in which the fish lives. Thus, the presence of dermal scutes and ossifications around the lateral-line besides giving protection to the fish in general and particularly to the structures they immediately surround, adds weight to the fish thereby increasing its density which is a contributory factor to bottom life and sluggish nature.

It may be noted that *Sisor rabdophorus* is the only Indian siluroid and at the same time unique among sisorids in possessing the dermal skeleton in the form of a series of bony plates on the back. Many Indian siluroids have dermal skeleton but only in the form of a nuchal shield (Regan 1911). Among catfishes, the bony armour is found only in the families Loricariidae and Callichthyidae (Bhatti 1938) of South America and Amphiliidae of Africa. All these forms are known to be sluggish and bottom living. Norman (1931, p. 96) commented on the South American forms thus:

> 'The mailed catfishes are sluggish creatures spending most of their time attached to stones or other objects at the bottom of a stream, and the bony armour provides them with an efficient protection against enemies.'

It must, however, be noted that the extent of dermal ossification is limited in case of *Sisor* as compared to most of the mailed members of South American and African families. Denticles, characteristic of South American mailed catfishes, are also absent. All this appears to have been made up to a certain extent by the development of what has been termed by me as 'cornified tubercles'. The conical cornified apices on these tubercles appear to serve the same purpose as the denticles in South American forms. Thus all over the dorsal and lateral surface of the body of the fish there are minute spine-like processes projecting in closely set groups. These spine-like processes are absent on the ventral side and the cornified cells have a flat outer surface. This is similar to the general absence or great reduction of bony armour on the ventral side in mailed catfishes; obviously it is not needed there.

It is significant to note that the cells of the outer layer of a typical cornified tubercle very closely resemble those forming the outer spiny layer of the special adhesive apparatus reported by Hora (1922), Bhatia (1950) and Saxena (1961) in various members of the family Sisoridae worked out by them. In hill-stream cyprinids, such as *Bhavania* (Hora 1922) and *Garra* (Saxena 1959), similar modifications have been reported. The basic modifications of the cell is essentially similar, each cell has a broad base with a distinct rounded nucleus and conical spine-like process. It appears that the same genetic tendency has led to the evolution of basically similar cell structure to serve the demands of different ecological niché, *viz.* adhesion in the case of inhabitants of hill streams (*Pseudecheneis, Glyptosternum*) and protection in the case of sluggish inhabitants of the comparatively calmer waters such as *Sisor.*

Moore (1950) has referred to structures somewhat similar to the cornified tubercles in some barbelled minnows (Cyprinidae) adapted to life in muddy waters. Thus he states: 'The skin of the head in *Macryhybopsis* (as also in *Extrarius aestivalis tetranemus* and to a lesser extent in *Hybopsis storerianus*) is densely covered with peculiar hitherto undescribed organs consisting of cells, each with a conical apex. These cells, in varying numbers, are arranged in clusters which occur most abundantly on the dorsal portion of the head in young specimens; in older fish they are more evenly distributed over the entire head. Whatever their function may be, there seems to be a correlation between the development of these structures and life in silty waters.' It will be noted that in the fishes studied by Moore (1950) these are confined to the head only whereas in *Sisor* they are distributed all over the body including the upper caudal filament. In young *Sisor*, these structures are more prominent; obviously the need for protection at that stage in life is greater. Similarly their abundance and formation of spine-like processes on the dorsal and lateral surfaces of the whole fish in *Sisor* is indicative of their protective function. On the basis of the present study, I entertain but little doubt that no special sensory function can be assigned to them.

The presence of taste buds all over the body, including the upper caudal filament, shows that the exploratory area for food is not confined to the region in and around the mouth only and that it is quite extensive. The upper caudal filament (which is usually more than $1\frac{1}{2}$ times the total length of the body) appears to serve a useful function by extending the exploratory area to more than twice the length of the fish not only posteriorly but also on the sides by its movement. Thus the fish can have some idea of the possible food sources around it without moving much. This would also account for the sluggish nature of the fish.

ACKNOWLEDGEMENTS

Grateful thanks are due to Dr. V. P. Agrawal, Head of the Zoology Department, D.A.V. College, Muzaffarnagar (U.P.), for guidance. I owe a debt of gratitude to Professor L. S. Ramaswami, D.Sc., F.N.I., for reading the manuscript and making many useful suggestions. I also wish to offer my sincere thanks to him for constant encouragement and facilities.

REFERENCES

Bhatia, B. (1950). *Proc. natn. Inst. Sci. India*, **16**, 271.

Bhatti, H. K. (1938). *Trans. zool. Soc. Lond.*, **24**, 1.

Bhatti, I. H. (1952). *Proc. natn. Inst. Sci. India*, B, **18**, 547.

Hasler, A. D. (1957). Olfactory and Gustatory Senses of Fishes. Chapter II, Part 3, in *The Physiology of Fishes*, vol. II, ed. M. E. Brown. Academic Press, New York, p. 187.

Hora, S. L. (1922). *Rec. Indian Mus.*, **24**, 31.

Mahajan, C. L. (1963). *J. Linn. Soc. Lond.*, **44**, 721.

Moore, G. A. (1950). *Trans. Am. microsc. Soc.*, **69**, 69.

Norman, J. R. (1931). A History of Fishes. Ernest Benn Limited, London.

Regan, C. T. (1911). *Ann. Mag. nat. Hist.*, **8** (eighth series), 553.

Sato, M. (1937). *Scient. Rep. Tohoku Imp. Univ.*, **2**, 323.

——— (1949). *Bull. Jap. Soc. scient. Fish*, **15**, 272.

——— (1955). *Bull. biol. Stn Asamushi*, **7**, 57.

——— (1956). *Annotnes zool. jap.*, **29**, 207.

——— (1962). *Annotnes zool. jap.*, **35**, 80.

Sato, M., and Kapoor, B. G. (1957). *Annotnes zool. jap.*, **30**, 156.

Saxena, S. C. (1959). *Proc. natn. Inst. Sci. India*, B, **25**, 205.

——— (1961). *Copeia*, **1961**, 471.

Van Oosten, J. (1957). The Skin and Scales. Chapter V, in *The Physiology of Fishes*, vol. I, ed. M. E. Brown. Academic Press, New York.

Wright, R. R. (1884). *Zool. Anz.*, **7**, 248.