Japanese Journal of Ichthyology
Vol. 33, No. 4 1987

魚類学雑誌
33巻4号 1987年

Interspecific Variations in the Surface Ultrastructure of the Gills of Freshwater Mullets

Jagdish Ojha, Ashok K. Mishra and Jyoti S. D. Munshi

(Received March 15, 1986)

Abstract SEM studies were made on the gills of freshwater mullets, *Rhinomugil corsula* and *Sicamugil cascasia*, to correlate surface ultrastructure of various gill units with their probable functions. Two types of lamellated gill rakers of the former fish are suited for plankton feeding and the short, stumpy and transversely beaded gill rakers of the latter reflect the varied food and feeding habit of the fish. *R. corsula* has numerous mucous glands on the epithelium covering the gill arch and gill filaments, *S. cascasia* has fewer. In accordance with the differences in the density and distribution of the mucous glands, the microridged epithelial cells also show variations in their architectural plan. In both species the epithelium of the secondary lamellae is smooth, probably an adaptation for better gaseous exchange.

Fish gills form an interface for gaseous and ionic exchange between the internal and external media. They are lined with different kinds of epithelia and cell types. The surface epithelium of the gills are modified in accordance with the physico-chemical factors of the habitat in which fishes live and flourish. Various studies have been made on the morphology (Duvernoy, 1839; Biétrix, 1895;Goodrich, 1930), histology (Keys and Wilmer, 1932; Bevelander, 1935; Munshi, 1960) and histochemistry (Singh and Munshi, 1968; Ojha and Munshi, 1974) of the fish gills. However, little is known (Hughes and Munshi, 1978; Hossler *et al.*, 1979; Hughes, 1979; Hughes and Mondolfino, 1983; Hughes and Umezawa, 1983; Karlsson, 1983) on the surface specializations of the fish gills.

The present work is an attempt to analyse the surface ultrastructure of the various gill units of the two freshwater mullets, *Rhinomugil corsula* and *Sicamugil cascasia* with special reference to their functions.

Materials and methods

Rhinomugil corsula (n=5) and *Sicamugil cascasia* (n=7) were collected from River Ganges near Bhagalpur (India) and were transported to and maintained in the animal house of the P. G. Department of Zoology, Bhagalpur University, Bhagalpur.

Without prior anesthetization the fishes were placed in 3% phosphate buffered glutaraldehyde. This ensured that the pumping action would quickly rinse the gills. After three minutes the fishes ceased ventilation and the gill filaments were removed carefully and fixed in 12% phosphate buffered glutaraldehyde and stored at 4°C for 48 h. The fixed materials were slowly dehydrated in a series of graded alcohols. Dehydrated specimens were critically point dried, immediately gold coated by vacuum evaporation and examined under SEM (PSEM/500) at RSIC, Bose Institute, Calcutta, India.

Observations

Gill rakers. In *R. corsula* (25 g), two types of gill rakers are arranged on the inner side of the four gill arches (Fig. 1). The dimensions of the gill rakers decrease successively from the first to the second, third and fourth gill arches. The first type of gill rakers on the first gill arch are long and slender with their main axis provided with lateral projections on the both sides (Fig. 1). The free edges of these rakers are swollen. The lateral projections are also seen at the tip of these rakers (Fig. 2). The other type of gill rakers are broad and lamellated. Its main axis also bears lamellar structures on its both sides. The epithelium covering the gill rakers is provided with mucous gland openings and microridged epithelial cells (Fig. 3). These rakers are oriented in such a fashion that they make an angle of about 120°

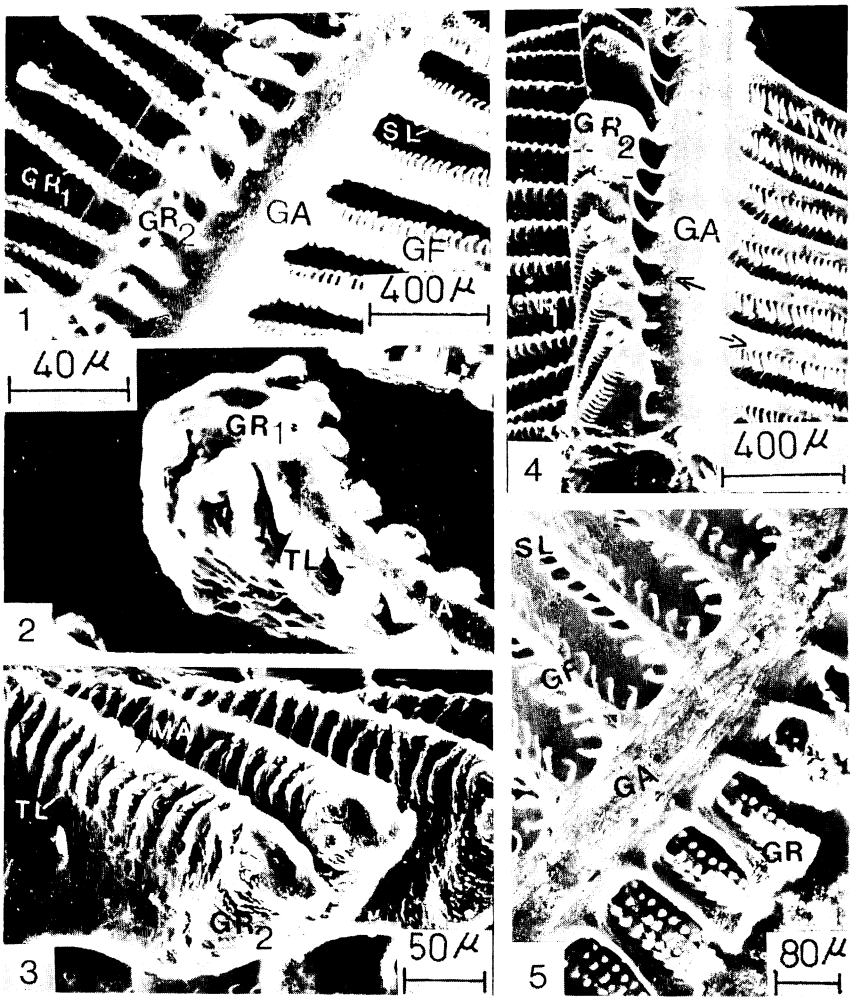

Fig. 1. Scanning micrograph of a part of the first gill of *Rhinomugil corsula* showing two types of gill rakers (GR_1, GR_2) on the gill arch (GA). Gill filaments (GF) and secondary lamellae (SL) are also seen.

Fig. 2. Scanning micrograph of a part of the gill raker (GR_1) on first gill arch of *R. corsula* showing swollen free edge and transverse lamellae (TL) attached to its main axis (MA).

Fig. 3. Broad gill rakers (GR_2) of the first gill arch of *R. corsula* showing the arrangement of transverse lamellae (TL) on the main axis (MA).

Fig. 4. Scanning micrograph of a part of the first gill of *R. corsula* showing orientation of two types of gill rakers (GR_1, GR_2) on the gill arch (GA). Mucous gland openings (arrows) are also seen on the gill arch and gill filaments.

Fig. 5. Scanning micrograph of a part of the first gill of *Sicamugil cascasia* showing short, stumpy and beaded gill rakers (GR) on the gill arch (GA). Mucous gland openings (arrow) are also seen on the gill arch (GA) epithelium. Biserial arrangement of secondary lamellae (SL) are seen on the gill filament (GF).

between them (Fig. 4). *S. cascasia* (5 g) has single type of gill rakers. These gill rakers are short and stumpy and provided with lateral projections (Fig. 5).

Gill arch. The epithelium covering the gill arch is differentiated into glandular and non-glandular parts. In *R. corsula* there are numerous mucous glands (Fig. 6) which constitute the glandular unit of the arch. The microridged epithelial cells (Fig. 7) constitute the non-glandular part

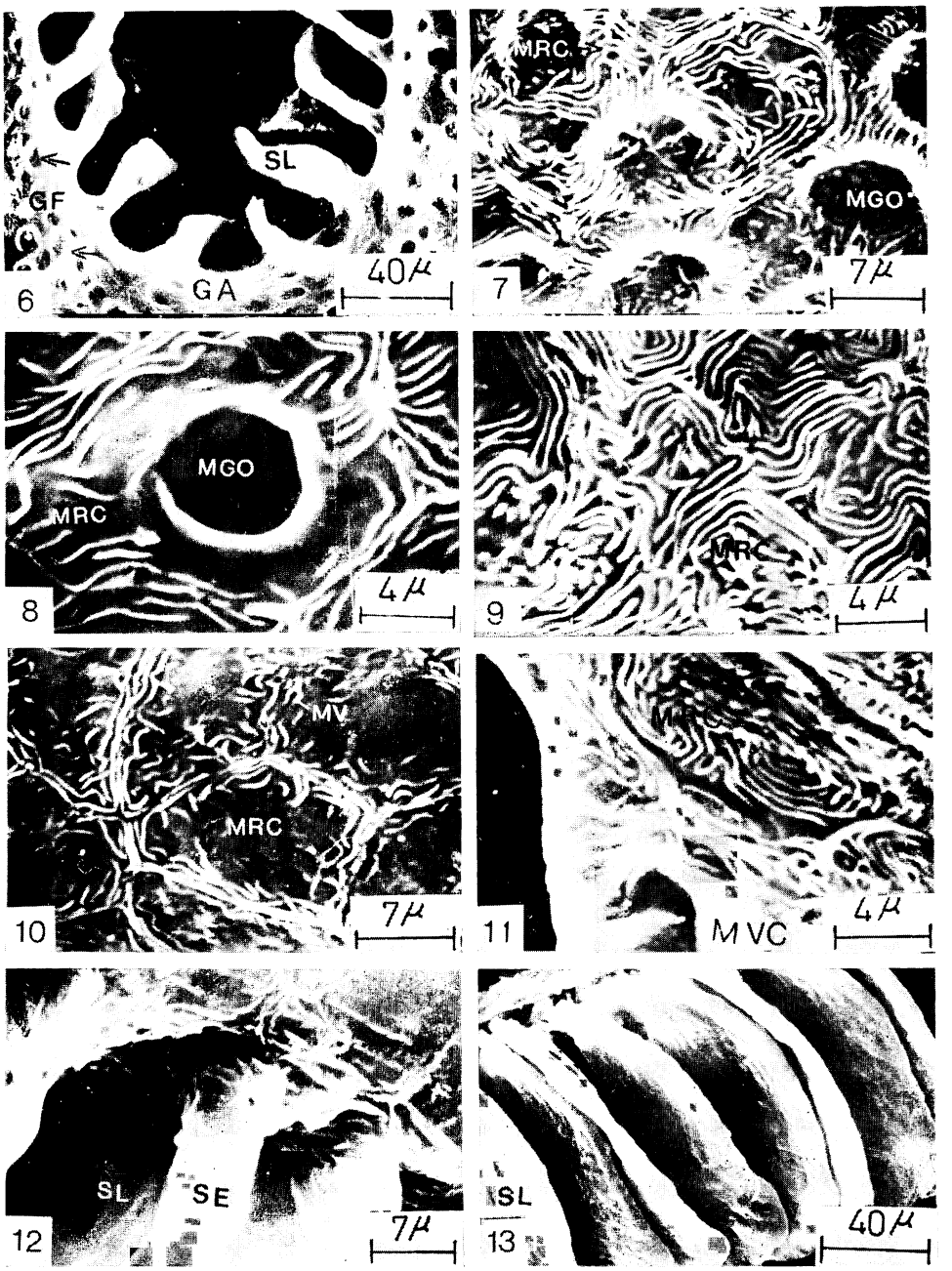

Fig. 6. Scanning micrograph of a part of the first gill of *R. corsula* showing numerous mucous gland openings (arrows) on the gill arch (GA) and gill filaments (GF). Secondary lamellae (SL) are also seen at the base of the inter lamellar space.

Fig. 7. Scanning micrograph of a part of the gill arch epithelium of the first gill of *R. corsula* showing mucous gland openings (MGO) and microridged epithelial cells (MRC).

Fig. 8. Scanning micrograph of a part of the primary epithelium of *S. cascasia* showing rim-like mucous gland opening (MGO) surrounded by microridged epithelial cells (MRC).

Fig. 9. Scanning micrograph of a part of the primary epithelium of the first gill of *R. corsula* showing architectural plan of the microridged epithelial cells (MRC).

of the arch. The plasma membrane of these cells are folded to form well-developed microridges.

In *S. cascasia*, the epithelium covering the gill arch is also provided with mucous cell openings and microridged epithelial cells. However, the number of mucous cell openings is lesser in comparison to that of *R. corsula*. Each mucous gland has a well-defined rim-like opening (Fig. 8). The arrangement and orientation of microridges are also different from those of *R. corsula*.

Gill filaments. Long and leaf-like gill filaments originate from the gill arch on the opposite side from the gill rakers (Fig. 1). On both sides of the gill filaments are arranged leaf-like secondary lamellae. The gill filaments are invested with primary epithelium which is provided with numerous mucous glands and microridged epithelial cells. The density, distribution and orientation of mucous glands in the primary epithelium are similar to that in the epithelium covering the gill arch. The plasma membrane of these cells are also folded to form well-developed microridges (Fig. 9). However, in *S. cascasia* mucous glands are fewer in number on the surface epithelium of the gill filament and the cells are provided with shorter ridges (Fig. 10).

Secondary lamellae. Leaf-like secondary lamellae are arranged on both sides of the gill filaments. The interlamellar space in *R. corsula* is greater than that of *S. cascasia*. Microridged epithelial cells are seen near the origin of secondary lamellae (Fig. 11). Near the base of secondary lamellae of *R. corsula* the secondary epithelial cells are provided with microvilli which seem to be a transitional phase between microridged primary epithelial cells and smooth secondary epithelial cells. The secondary epithelium is almost smooth in both the mullets (Figs. 12, 13).

Discussion

Surface ultrastructure of the various gill components of mullets under SEM reveals many interesting features. Well-developed lamellated gill rakers and their typical orientation are correlated with the phytoplanktonic feeding habit of the fish. The densely packed and complex gill rakers of *R. corsula* add to the efficacy of the detection and capture of food flowing through irrigating water. The mechanism is made even more perfect by dividing the axes of primary gill rakers into small lamellae. The short and stumpy gill rakers of *S. cascasia* reflect its different food and feeding habit. The presence of whorl-like microridges in the surface epithelium of the gill rakers is perhaps associated with the holding of mucus secreted by goblet cells. The mucus in these mullets may serve to increase the efficacy of gill rakers by cleaning the surface and exposing the chemoreceptors (taste-buds) for the detection of food and chemical characteristics of the ambient water.

The arrangement and density of gill rakers are specific for different fishes and may be a guideline for determining food and feeding habit and the taxonomic status of the fish.

The present SEM studies further reveal interspecific variations in the epithelium of the gill arches of the two mullets. *R. corsula* has numerous mucous glands in the epithelium lining the gill arch than that of *S. cascasia*, which has a fewer number of mucous glands. In accordance with numerous mucous glands the surface epithelium has well-developed microridged cells. These microridges may help to hold mucus secreted by a large number of goblet cells and regulated the velocity of irrigating water by creating microturbulence (Hughes, 1979). The architectural

Fig. 10. Scanning micrograph of a part of the primary epithelium of the first gill of *S. cascasia* showing microvilli (MV) in the microridged epithelial cells (MRC).

Fig. 11. Scanning micrograph of a part of the origin of secondary lamellae of the first gill of *R. corsula* showing microridged epithelial cells (MRC) and microvillar epithelial cells (MVC).

Fig. 12. Scanning micrograph of a part of the gill filament on the first gill of *R. corsula* showing smooth secondary epithelium (SE) on the secondary lamellae (SL).

Fig. 13. Scanning micrograph of a part of the gill filament of the first gill of *S. cascasia* showing smooth surfaced secondary lamellae (SL).

plan of the microridges in the surface epithelial cells is also different in both the mullets. From these findings it can be suggested that the surface ultrastructure of the gill arch is specific for different fish species.

Like gill arch, the filaments are also lined by surface epithelium. The epithelium is termed as primary epithelium (Laurent and Dunel, 1980). The cells of the primary epithelium have also been termed as pavement cells (Copeland, 1948; Karnaky *et al.*, 1976), but have often been referred to simply as epithelial cells (Straus, 1963; Philpott, 1965; Shirai and Utida, 1970) and sometimes as respiratory epithelial cells (Straus, 1963). Hossler *et al.* (1979) suggested the term "ridged epithelial cells" for the primary epithelial cells. Hughes (1979) used the term "micro-ridged cells" for the cells covering the gill filaments. With respect to inconsistencies in the terminology it is suggested to designate these cells as micro-ridged epithelial cells. Various functions have been assigned to the microridged epithelial cells of the primary epithelium (Olson and Fromm, 1973; Hossler *et al.*, 1979; Hughes, 1979; Hughes and Umezawa, 1983). Presence of whorl-like microridges in the primary epithelial cells in *R. corsula* is associated with the packing of these cells with greater surface area in specified space. In primary epithelium also these microridges may produce micro-turbulence of water beside anchoring mucus produced by the epithelial cells.

Primary epithelium also shows variations in the surface specializations of both the mullets. The differences are mainly in the density of mucous glands and the pattern of microridges in the primary epithelial cells. However, there was no change in the density, distribution and the architectural plan of the mucous glands and microridged epithelial cells on the base, middle and tip of the filaments of *R. corsula*. Further, the architectural plan of the primary epithelium was similar to that of the epithelium investing the gill arch. However, in *S. cascasia* there was marked difference in the epithelium covering the gill arch and gill filaments. These findings suggest inter- and intra-specific variations in the architectural plan of the epithelium, covering the arch and gill filaments.

In both the mullets, the secondary lamellae are invested with smooth secondary epithelium which lacks mucous cells and microridged epithelial cells. In these fishes absence of ridges on epithelial cells is an adaptation for efficient gaseous exchange. Presence of microridged epithelial cells full of mucus may increase the water-blood distance in the lamellae. This situation is not favourable for effective gaseous exchange. A smooth secondary epithelium minimizes the water-blood distance and enhances the efficacy of gills. In *R. corsula* the presence of microvillous epithelial cells at the lower-margins of the secondary lamellae indicates a transitional phase between microridged epithelial cells of the gill filaments and the smooth surfaced epithelial cells of the lamellae. These findings suggest variation in the surface ultrastructure of the primary and secondary epithelia. These variations are obviously due to their varied functions.

Acknowledgments

The authors wish to thank RSIC, Bose Institute, Calcutta for providing SEM facilities. Financial assistance was provided by CSIR (7/24/44/80-81-EMR-I).

Literature cited

Bevelander, G. 1935. A comparative study of the branchial epithelium in fishes with special reference to extrarenal excretion. J. Morph., 57: 335–351.

Biétrix, E. 1895. Quelques considérations sur les notions de lacune et d'endothélium en anatomie générale, a propos du réscus vasculaire branchial des poissons. C. R. Somm. Séanc. Soc. Philomath. Paris, 8: 26–28.

Copeland, D. E. 1948. The cytological basis of chloride transfer in the gills of *Fundulus heteroclitus*. J. Morph., 82: 201–227.

Duvernoy, M. 1839. Du mechanisme de la respiration des poissons. Ann. Sci. Nat. (Zool.), 12: 65–91.

Goodrich, E. S. 1930. Studies on the structure and development of vertebrates. Macmillan, New York.

Hossler, F. E., J. R. Rubey and T. D. Mcilwain. 1979. The gill arch of the mullet, *Mugil cephalus* I. Surface ultrastructure. J. Exp. Zool., 208: 379–397.

Hughes, G. M. 1979. Scanning electron microscopy of the respiratory surfaces of the trout gills. J. Zool., 187: 443–453, pls. I–III.

Hughes, G. M. and R. M. Mondolfino. 1983. Scanning electron microscopy of the gills of *Trachurus mediterraneus*. Experientia, 39: 518–519.

Hughes, G. M. and J. S. D. Munshi. 1978. Scanning

electron microscopy of the respiratory surfaces of *Saccobranchus* (*Heteropneustes*) *fossilis* (Bloch). Cell Tiss. Res., 195: 99–109.

Hughes, G. M. and S. Umezawa. 1983. Gill structure of the yellow tail and frog fish. Japan. J. Ichthyol., 30: 176–183.

Karlsson, L. 1983. Gill morphology in the zebra fish, *Brachydanio rerio* (Hamilton-Buchanan). J. Fish. Biol., 23: 511–524.

Karnaky, K. J., S. A. Ernst and C. W. Philpott. 1976. Teleost chloride cell. I. Response of pupfish, *Cyprinodon variegatus* gill Na, K-ATPase and chloride cell fine structure to various high salinity environments. J. Cell Biol., 70: 144–156.

Keys, A. and E. N. Wilmer. 1932. "Chloride secreting cells" in the gill of fishes, with special reference to the common eel. J. Physiol., London, 76: 568–578.

Laurent, P. and S. Dunel. 1980. Morphology of gill epithelia in fish. Am. J. Physiol., 238: 147–159.

Munshi, J. S. D. 1960. The structure of the gills of certain freshwater teleosts. Ind. J. Zool., 1: 135–174, pls. I–XVII.

Ojha, J. and J. S. D. Munshi. 1974. Histochemical and histophysiological observations on the specialized branchial glands of a freshwater mud-eel, *Macrognathus aculeatum* (Bloch). Mikroskopie, 30: 1–16.

Olson, K. R. and P. O. Fromm. 1973. A scanning electron microscopy study of secondary lamellae and chloride cells of rainbow trout (*Salmo gairdneri*). Z. Zellforsch. Microsk. Anat., 143: 439–449.

Philpott, C. W. 1965. Halide localization in the teleost chloride cell and its identification by selected area electron diffraction. Direct evidence supporting an osmoregulatory function for the sea water adapted chloride cell of *Fundulus*. Protoplasma, 60: 7–23.

Shirai, N. and S. Utida. 1970. Development and degeneration of the chloride cell during sea water and freshwater adaptation in the Japanese eel *Anguilla japonica*. Z. Zellforsch. Mikrosk. Anat., 3: 247–264.

Singh, B. N. and J. S. D. Munshi. 1968. Cytology and cytochemistry of the granular cells found in the gills of certain freshwater teleosts. Mikroskopie, 23: 11–25.

Straus, L. P. 1963. A study of the fine structure of the so called chloride cell in the gill of the guppy, *Lebistes reticulatus*. P. Physiol. Zool., 36: 183–198.

(Post-Graduate Department of Zoology, Bhagalpur University, Bhagalpur-812007 (Bihar), India)

淡水ボラの鰓表面の微細構造の種間変異

Jagdish Ojha·Ashok K. Mishra·Jyoti S. D. Munshi

淡水ボラの *Rhinomugil corsula* と *Sicamugil cascasia* の鰓の構造を走査電子顕微鏡によって調べた．前者の葉状の鰓弁はプランクトン食性に適しており，後者の太くて短い鰓弁は様々な食物を摂取することを反映している．前者は鰓弓と鰓葉を覆う上皮に多数の粘皮細胞の構造も異なる．両種とも二次鰓弁の上皮は円滑である．これはガス交換のための適応と考えられる．