Comparative Morphology of Fish Olfactory Epithelium—II
Clupeiformes

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(Received February 27, 1978)

The olfactory rosettes of five species of Clupeiformes were studied by scanning and transmission electron microscopy. They are all oval in shape, consisting of 24–30 unfolded lamellae. Each lamella is composed of centrally located sensory epithelium encircled by marginal indifferent epithelium. In Etrumeus teres and Engraulis japonica, the sensory epithelium contains three types of cells, i.e., cells projecting 3–5 relatively long cilia radially from a round cell apex (type 2 ciliated cells), cells bearing a tuft of long microvilli (microvillous cells) and supporting cells provided with short microvilli. In Harengula zunasi, Sardinops melanosticta and Konosirus punctatus, cells bearing many cilia in a tuft (type 1 ciliated cells) are sparsely scattered in the sensory epithelium in addition to the above three cell types. Apical cytoplasm of supporting cells in Etrumeus is filled with large electron-lucent droplets.

In the first paper of this series1), we have reported that the olfactory lamellae of the Salmoniformes consist of the indifferent and the sensory epithelium and the following five types of cells are distinguishable in the sensory epithelium on the basis of their surface feature: type 1 ciliated cell bearing many cilia in a tuft; type 2 ciliated cell projecting several cilia radially from a round cell apex; microvillous cell having a tuft of numerous microvilli; rod cell protruding a simple rod; and supporting cell provided with short microvilli.

The Clupeiformes is generally believed to be visually orienting fish without acute sense of smell2,3). To our knowledge, olfactory organs of this group have not been examined by electron microscopy. In the present report, we deal with an electron microscopic observation of olfactory lamellae in five species of the Clupeiformes.

Materials and Methods

The following five species of the Clupeiformes were used: Japanese scaled sardine* (Harengula zunasi) about 10 cm long, spotted sardine (Sardinops melanosticta) about 12 cm long, dotted gizzard shad (Konosirus punctatus) about 15 cm long, round herring (Etrumeus teres) about 10 cm long and Japanese anchovy (Engraulis japonica) about 10 cm long. Japanese scaled sardine and dotted gizzard shad were obtained in Lake Hamana in October and the other species were collected in July near the Misaki Marine Biological Station, Miura Peninsula.

Olfactory organs were fixed and prepared for transmission and scanning electron microscopy in the same way as described in the previous paper.1) The electron microscopes used were a Hitachi HS-8 and a JEOL JSM-35.

Results and Discussions

In five species investigated, the olfactory rosettes are similar to one another in the external shape. They are oval in outline, consisting of lamellae radiating from a central axis (Figs. 1 and 2). The number of lamellae was 24 for Sardinops melanosticta 26 for Konosirus punctatus and Harengula zunasi (Fig. 2), 28 for Engraulis japonica and 30 for Etrumeus teres (Fig. 1). The lamellae decrease in size from caudal to rostral. Each lamella has unfolded faces with a concave and a convex free margin (Figs. 3 and 4).

The lamella is composed of ciliated sensory epithelial region and non-ciliated indifferent epithelium and non-ciliated indifferent epithelium.

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The indifferent epithelium forms a continuous zone along the free margin of lamella, encircling centrally located sensory epithelium. This zone is relatively narrow in Engraulis japonica (Fig. 3) and Etrumeus teres, intermediate in Sardinops melanosticta and Harengula zunasi, and broad in Konosirus punctatus (Fig. 4). In Harengula zunasi and Konosirus punctatus, small islands of indifferent epithelium are scattered in the sensory epithelial region (Figs. 4 and 8). The central axis of the olfactory rosette is also covered with indifferent epithelium. The free surface of the indifferent epithelial cell shows a fingerprint-like pattern of microridges (Fig. 8) which is generally observable in the epidermal surface of teleosts.4)

The sensory epithelium is not ciliated so densely that the free surface of each cell is easily visible in scanning electron micrographs. In the sensory epithelium of Engraulis japonica and Etrumeus teres, type 2 ciliated cells and microvillous cells are scattered among supporting cells (Figs. 6 and 7). Neither type 1 ciliated cells nor rod cells could be found in these species. In Sardinops melanosticta, Harengula zunasi and Konosirus punctatus, a small number of type 1 ciliated cells are present in addition (Figs. 8 and 9). The cells of each type resemble one another among the five species investigated. Type 1 ciliated cells bear a ciliary tuft composed of 20–30 cilia bending in the same direction (Fig. 9). Type 2 ciliated cells project 3–5 relatively long cilia (6–8 μm in length) radially from a cell apex protruding as a hillock (Figs. 7 and 9). Microvillous cells have a relatively small number of long microvilli (about 3 μm in length) (Figs. 7 and 9). Supporting cells have a flat free surface provided with short microvilli (Figs. 7 and 9).

In sections of the sensory epithelium in Etrumeus teres (Fig. 5), type 2 ciliated cells and microvillous cells are seen as slender cells about 1 μm in width near the apical end, occurring between every one to three supporting cells. Supporting cells have a relatively broad free surface (1–3 μm in width). Their apical cytoplasm is filled with many droplets about 0.5 μm in diameter with electron-lucent fibrous content (Fig. 5). These droplets may represent material(s) that is possibly secreted into the mucus.

Olfactory acuity in fish has been estimated on the basis of behavioral and anatomical data2,3,5) and some quantitative data such as threshold concentration of odorous substances5,6). It is generally accepted that eels, salmons, catfishes and cods have acute olfactory sensitivity and use mainly olfactory cues in their behaviors, whereas cyprinodonts and sticklebacks rely mainly on visual sense5). Herrings seem to belong to the latter group. They are active in daytime, show strong phototaxis and search food mainly by means of sight1,3). UCHIHASHI6) has reported that in some species of the Clupeiformes including five species examined in the present study, optic lobe is well developed but olfactory lobe is small in size.

It is of interest to compare the present results with those obtained in salmons1). The main differences in the morphological feature of the olfactory epithelium between salmons and herrings are: (1) that in herrings, type 1 ciliated cells are sparse or completely lacking and rod cells are not observed at all, (2) that olfactory epithelium is more densely ciliated in salmons than in herrings, (3) that the numbers of cilia and microvilli, arising respectively from a type 2 ciliated cell and a microvillous cell, are both larger in salmons than in herrings. Olfactory epithelium of macrosmatic fish, such as eels7,8), cods9,10) and catfishes11), is also covered very densely with cilia mostly from type 1 ciliated cells and contains cells corresponding to type 2 ciliated cells, microvillous cells and rod cells. In contrast, the olfactory epithelium of microsmatic fish, such as cyprinodonts12) and sticklebacks13,14) comprises mainly two cell types (type 2 ciliated cells and microvillous cells) and lacks type 1 ciliated cells.

Acknowledgements

We express our sincere thanks to Dr. Fujio YASUDA, Tokyo University of Fisheries, for his kind arrangements for collection of fish, Dr. Tadashi NONAKA, the Fisheries Experimental Station of Shizuoka Prefecture and the staff of the Misaki Marine Biological Station for kindly supplying fish.

References

Figs. 1 and 2. An olfactory rosette of round herring (Fig. 1, ×45) and Japanese scaled sardine (Harengula zunasi) (Fig. 2, ×40).

Figs. 3 and 4. An isolated olfactory lamella of Japanese anchovy (Engraulis japonica) (Fig. 3, ×300) and dotted gizzard shad (Konosirus punctatus) (Fig. 4, ×270). IE, indifferent epithelium; SE, sensory epithelium. Arrows in Fig. 4 indicate islands of indifferent epithelium.

Fig. 5. Section of sensory epithelium in the olfactory lamella of round herring (Etrumeus teres). c2, type 2 ciliated cell; m, microvillous cell; s, supporting cell. ×16,000.
Figs. 6 and 7. Sensory epithelium in the olfactory lamella of round herring (*Etrumeus teres*). c2, type 2 ciliated cell; m, microvillous cell; s, supporting cell. Fig. 6, ×3,000; Fig. 7, ×8,000.

Figs. 8 and 9. Sensory epithelium in the olfactory lamella of dotted gizzard shad (*Konosirus punctatus*). c1, type 1 ciliated cell; c2, type 2 ciliated cell; IE, indifferent epithelium; m, microvillous cell; s, supporting cell. Fig. 7, ×3,000; Fig. 9, ×8,000.