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Functional Anatomy of the Olfactory Organs in the Moray, *Muraena undulata*

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Abstract The anatomy of the olfactory organs in the moray, *Muraena undulata*, has been studied. It has an elongated rosette which has been placed in Burne's (1909) rosette column II and in Bateson's (1889) rosette type 2. The olfactory surface in *M. undulata* is very extensively developed. The species is a macrosmat and has been classified with Teichmann's (1954) group 3 of nose fishes.

Introduction

The structure and function of the olfactory organs in fishes have been previously studied by various workers. Notable contributions in this respect are those of Bateson (1889), Burne (1909), Derscheid (1924), Van den Berghe (1929), Liermann (1933), Teichmann (1954), Branson (1963), Gooding (1963), and Pfeiffer (1963, 1964, 1965). Kleerekoper (1969) has extensively reviewed the previous work on the subject. A perusal of the literature reveals that Indian species have so far not been investigated. A study of these organs in several Indian teleosts was, therefore, initiated with a view to obtain a comparative data about them in forms derived from different taxonomic levels and varying habitats. This article sums up the results obtained for the moray, *Muraena undulata* Lacépède, collected from the Mahara shthra coast of India.

Material and methods

Heads of adult specimens of *M. undulata,* fixed in Bouin's fluid or 10% formalin, were dissected from the dorsal side to expose for study the olfactory rosettes and their connections with the brain. Dried and alizarin treated skulls were made to examine the relations of the olfactory chambers with various skull bones. Transverse and horizontal paraffin sections of Bouin and Zenker-fixed rosettes were cut at 6–8 μ thickness and stained with Mallory's aniline blue collagen stain and Delafield's haematoxylin, counterstained with eosin. Teichmann's (1954) method was followed for calculating the olfactory and retinal areas of the fish.

Observations

The olfactory organs of *M. undulata* consist of paired olfactory chambers situated on the dorsal surface of the snout. The position of each chamber is marked externally by an anterior opening borne on a forwardly directed tube and a posterior oval opening situated immediately above the anterodorsal edge of the eye (Fig. 1). The posterior opening is not supported on a tube, but is provided with a slightly raised margin. The two openings are situated at a distance from one another and mark the anterior and posterior ends of the olfactory chamber.

In *M. undulata,* the olfactory bulbs are absent. The paired olfactory tracts are short and thick. Each tract is formed by olfactory fibers emerging from the posteromesial surface of the olfactory chamber. After passing through the olfactory foramen, it runs backward through the frontal region of the skull and eventually merges with the anterior end of the prominently developed olfactory lobe (Fig. 2). For the most part, the two tracts of

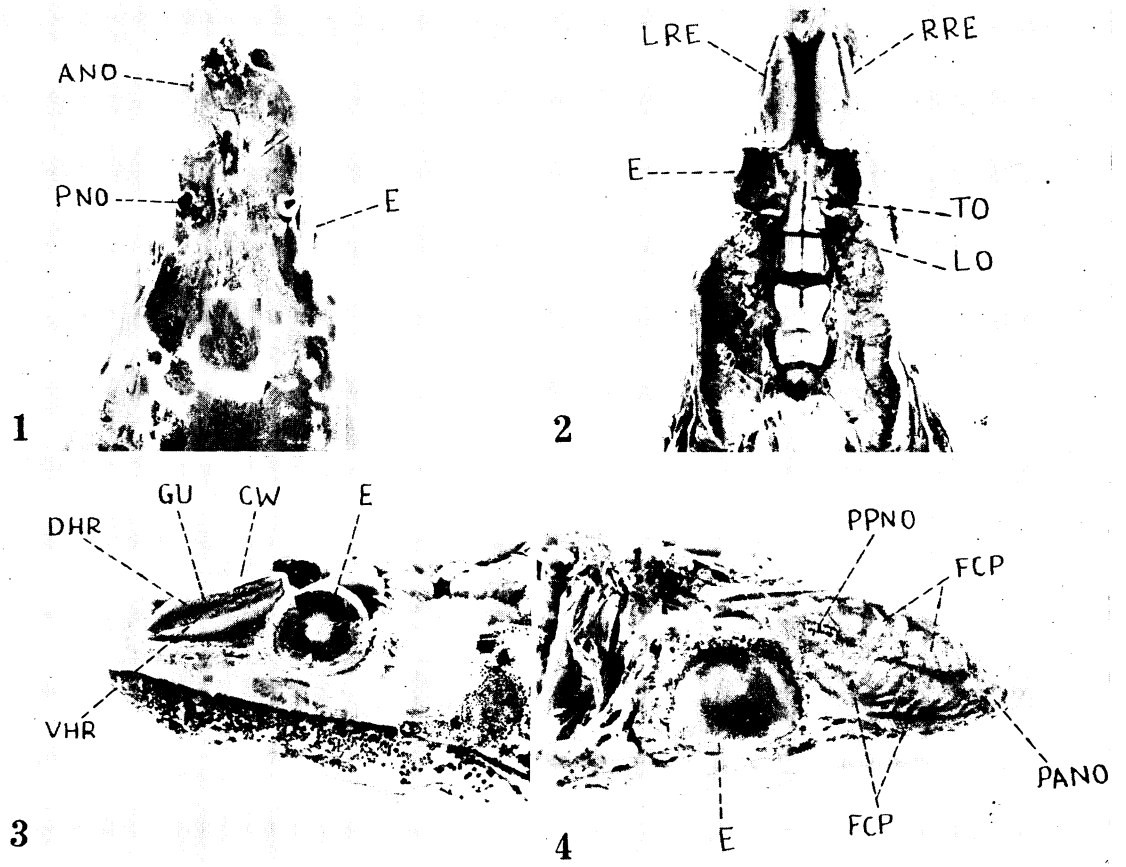


Fig. 1. Dorsal view of the head of *Muraena undulata* to show the two nasal openings. ANO, anterior nasal opening; E, eye; PNO, posterior nasal opening.

Fig. 2. Dissection of the head of *M. undulata* from the dorsal side to show the relationship of brain with the olfactory rosettes. E, eye; LO,olfactory lobe; LRE, left rosette; RRE, right rosette; TO, olfactory tract.

Fig. 3. Lateral view of the left olfactory rosette of *M. undulata*. CW, wall of the olfactory chamber; DHR, dorsal half of the rosette; E, eye; GU, gutter; VHR, ventral half of the rosette.

Fig. 4. Lateral view of the right olfactory chamber of *M. undulata*, showing fibrocartilaginous processes of the nasal and lachrymal bones. E, eye; FCP, fibrocartilaginous processes; PANO, position of anterior nasal opening; PPNO, position of posterior nasal opening.

the right and left sides lie close together.

The elongated olfactory chamber bearing the rosette (Fig. 3) is lodged in a fossa formed in the ethmoidal region of the skull (Figs. 5A, B) and is attached to the surrounding bones by fibrous connective tissue. It lies immediately anterior to and more or less at the level of the eye. An accessory nasal sac is absent. The mesial end of the olfactory chamber is bounded dorsally by the long, narrow, and tubular nasal situated along the lateral margin of the ethmoid (Fig. 5B). The posterior part of the nasal is comparatively broader and takes part in the formation of the dorsal boundary of the orbit. A well-developed sheath of fibrous connective tissue covers the olfactory chamber along its outer surface. Thin and curved fibrocartilaginous processes arise from the nasal and extend outward and downward over the olfactory chamber where they get embedded in this fibrous sheath (Figs. 4, 5A). The lachrymal is an angular bone

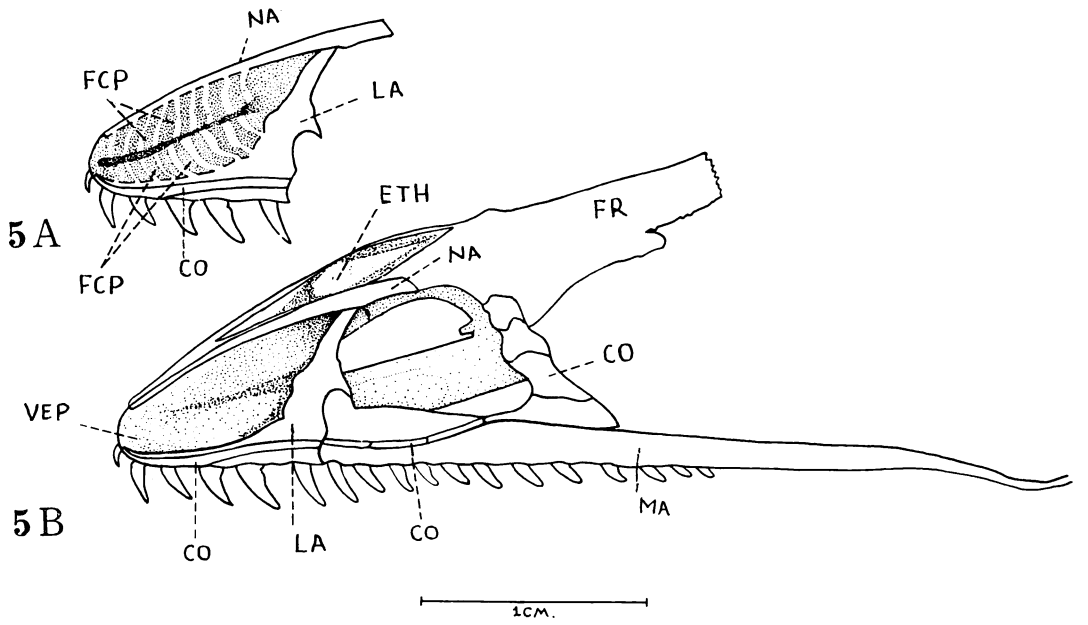


Fig. 5A. Lateral view of ethmoidal region of the skull of *M. undulata* to show the position of the olfactory chamber; fibrocartilaginous processes of the nasal and lachrymal bones are also shown. 5B. Lateral view of the anterior part of the skull of *M. undulata* (lower jaw not shown). CO, circumorbitals; ETH, ethmoid; FCP, fibrocartilaginous processes; FR, frontal; LA, lachrymal; MA, maxilla; NA, nasal; VEP, vomerethmoid-premaxillary.

with an anterior long and spiny horizontal limb and a posterior vertical limb. The main body of the lachrymal articulates with the dorsal knob of the anterior extremity of the maxilla (Fig. 5B). The posterior vertical limb of the lachrymal articulates dorsally with the posterior part of the ethmoid along its lateral margin. This limb of the lachrymal bounds the olfactory chamber along its hinder margin and at the same time forms the anterior boundary of the orbit (Fig. 5B). In collaboration with the ethmoid bone, it also takes part in the formation of the foramen for the passage of the olfactory tract. The anterior horizontal limb of the lachrymal bounds the olfactory chamber along its outer ventral margin. From this limb arise fibrocartilaginous processes (like those developing from the nasal), which extend outward and upward over the olfactory chamber where they get embedded in the fibrous sheath described above (Figs. 4, 5A). The ethmoid, premaxilla, and vomer have fused together to form a complex vomer-ethmoid-premaxillary

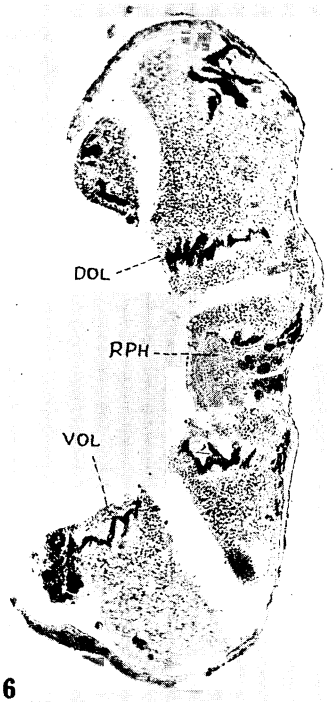
Fig. 6. Transverse section through the anteriormost part of the rosette of a specimen of *Muraena undulata* with a total length of 410 mm. ×60. DOL, dorsal olfactory lamellae; RPH, raphe; VOL, ventral olfactory lamellae.

Fig. 7. Transverse section through the posterior part of the rosette of a specimen of *M. undulata* with a total length of 410 mm. ×20. CW, wall of the olfactory chamber; DOL, dorsal olfactory lamellae; RPH, raphe; VOL, ventral olfactory lamellae.

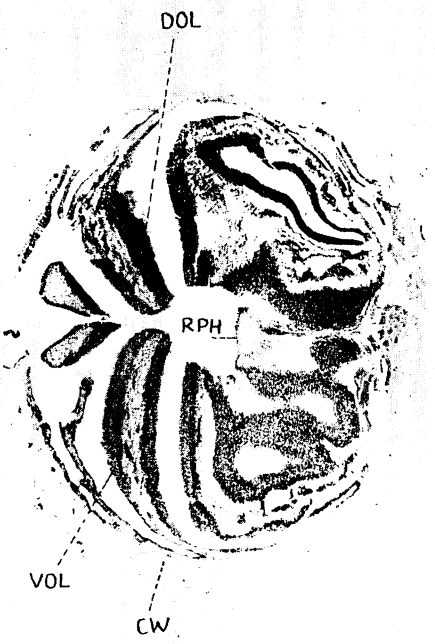
Fig. 8. Horizontal section of dorsal half of the rosette of a specimen of *M. undulata* with a total length of 390 mm. ×28. CW, wall of the olfactory chamber; OL, olfactory lamellae.

Fig. 9. Photomicrograph of an olfactory lamella of a specimen of *M. undulata* with a total length of 515 mm. ×28. DM, dorsal margin; IE, inner end; OE, outer end; VM, ventral margin.

Fig. 10. Complete set of 92 lamellae of the ventral half of left rosette of a specimen of *M. undulata* with a total length of 585 mm; beginning from the anterior end, the lamellae are serially numbered.


DOL
RPH
VOL

6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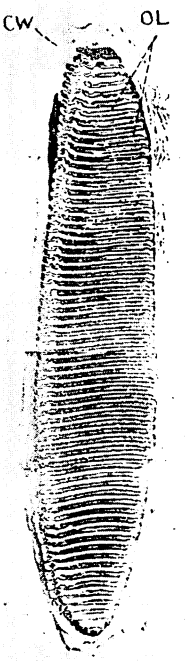
CW
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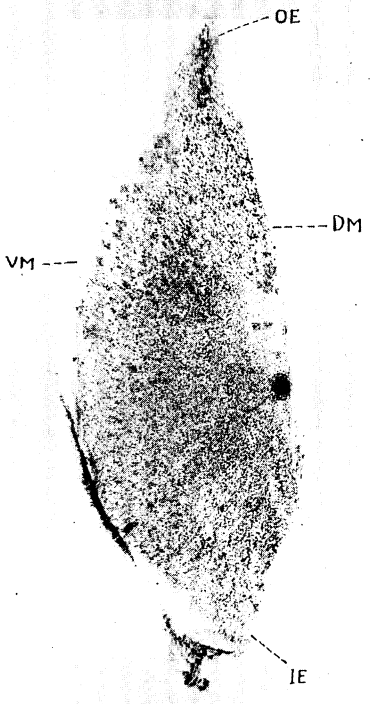
8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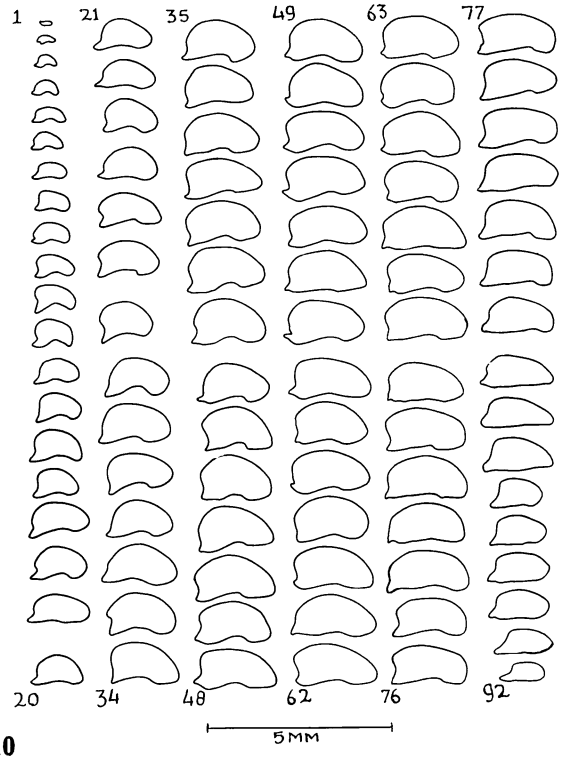
1
21
35
49
63
77
20
34
48
62
76
92
5MM

10

Table 1. Number of olfactory lamellae in *Muraena undulata*.

Total length of fish in mm	Number of olfactory lamellae		Total number of lamellae in both rosettes
	Left rosette	Right rosette	
370	129	132	261
465	151	153	304
525	165	169	334

bone which bounds the long olfactory chamber all along its mesial and ventral surfaces (Fig. 5B).

The elongated olfactory rosette occupies the entire cavity of the large olfactory chamber (Fig. 3). The long axis of the rosette roughly extends along the same plane as the antero-posterior axis of the body of the fish. At the mesial end of the olfactory rosette is a long and narrow raphe extending along its long axis. The olfactory rosette, which is large and compact, is roughly divisible into almost equal dorsal and ventral halves (Fig. 3). From the dorsal and ventral walls of the olfactory chamber, on either side of the raphe, arise a dorsal and a ventral row of olfactory lamellae (Figs. 6, 7). Each of these rows comprises of a large number of closely arranged, slightly swollen lamellae (Figs. 8, 9). The anteriormost lamellae in both these rows are the smallest (Fig. 10). The lamellae in *M. undulata* are devoid of linguiform processes (Fig. 9). The anterior and posterior lamellae are attached obliquely on the raphe, but the middle ones are arranged more or less perpendicular to it.

The lamellae in both the dorsal and ventral rows are attached to the raphe by their inner or mesial ends. The dorsal lamellae are attached to the wall of the olfactory chamber along their convex dorsal margins and hang vertically downward, whereas the ventral lamellae are attached to the wall of the olfactory chamber along their ventral convex margins and project vertically upward (Fig. 7). The result is that the free dorsal margins of the ventral lamellae and the free ventral margins of the dorsal lamellae face each other along a horizontal plane which divides the rosette into the dorsal and ventral halves (Figs. 3, 7). The opposing free margins of the dorsal and ventral lamellae of the posterior part of the rosette come so close to each other that they leave very little space between them (Figs. 3, 7). The free margins of the dorsal and ventral lamellae of the anteriormost part of the rosette do not come so close to each other (Figs. 3, 7); between the dorsal and ventral lamellae of this region, therefore, is formed a gutter which is wider anteriorly and narrows posteriorly (Fig. 3). The outer ends of the posterior lamellae in both the dorsal and ventral rows abut against the posterior nasal opening in a manner which might prevent the entry of water from outside into the olfactory chamber through this opening (Fig. 4).

Adult specimens of different sizes were examined to determine the number of lamellae present in their olfactory rosettes (Table 1). The total number of lamellae in both the rosettes showed an increase with a corresponding increase in the size of fish. The surface area of the lamellae in both rosettes of a fish measuring 525 mm was calculated and was found to be about 1463% of the surface area of the two retinae of the fish:

Number of lamellae in both rosettes...334
Area of the two retinae of the fish...132.6 mm^2
Surface area of lamellae in the two rosettes .....1931.8 mm^2

Discussion

The anterior nasal opening in *M. undulata* is supported on a forwardly and outwardly directed ciliated tube. This confirms Burne's (1909) earlier observation that tubular anterior openings are chiefly, though not exclusively,

found in eels including the moray (besides flatfishes, siluroids, and snakeheads). The present authors have observed that when the anterior and posterior openings in a fish are separated by some distance, the former is invariably borne on a tube. Bateson (1889) postulated that tubular anterior openings are characteristic of fishes possessing a well-developed olfactory faculty. This appears to be plausible and we have observed during the course of our study that such fishes do possess relatively extensive olfactory surfaces. This has, however, not yet been substantiated through experimental means. The ciliated nature of anterior tubular openings has been widely reported (Bateson, 1889; Burne, 1909; Parker and Sheldon, 1912; Pipping, 1926, 1927; Van den Berghe, 1929; Liermann, 1933; Teichmann, 1959, 1962). The cilia of these tubular openings and of the general olfactory epithelium facilitate the flow of water current through the olfactory chamber of the fish. The posterior nasal opening in *M. undulata* occurs as a simple oval perforation with a slightly raised margin. Contrary to this, Weidersheim (1906) and Burne (1909) have described tubular posterior openings in the case of *M. helena* and *M. tigrina,* respectively.

The elongated rosette of *M. undulata,* with a narrow central raphe, can be classified with Bateson's (1889) rosette type 2 and under Burne's (1909) rosette column II. The olfactory lamellae in *M. undulata* do not bear linguiform processes. Their number increases with the increase in the age and size of the fish; the smallest lamellae are always found at the anterior end of the rosette which should imply that its growth occurs at this end. In the burbot (Pfeiffer, 1965) and salmon (Teichmann, 1954; Pfeiffer, 1963), the number of olfactory lamellae reportedly remains constant after a certain level in growth of the fish is reached. Adequate data in this context for other fishes are not available. We do not find it to be true for any of the eight species of teleosts (including catfishes, carps, flatfish, snakehead, and the moray) studied by us so far and we believe that any generalization of this kind, in order to be acceptable, should be based on an examination of a sufficiently large number of fishes.

The total olfactory area in *M. undulata* has been found to be 1463% of its total retinal area. With such an extensively developed olfactory surface, this species should be placed in Teichmann's (1954) group 3 of nose fishes. In other words, it is a macrosmatic species and has a predominantly developed olfactory faculty.

Literature cited

Bateson, W. 1889. The sense organs and perceptions of fishes, with remarks on the supply of bait. J. Mar. Biol. Assoc. London, 1: 225–256, figs. 1–17.

Branson, B. A. 1963. The olfactory apparatus of *Hybopsis gelida* (Girard) and *Hybopsis aestivalis* (Girard). J. Morph., 113: 215–229, pls. 1–4.

Burne, R. H. 1909. The anatomy of the olfactory organ of teleostean fishes. Proc. Zool. Soc. London, 2: 610–663, figs. 188–213.

Derscheid, J. M. 1924. Structure de l'organe olfactif chez les poissons. Première partie. Osteichthyes, Teleostei, Malacopterygii. Ann. Soc. Roy. Zool. Belg., 54: 79–162, figs. 1–26.

Gooding, R. M. 1963. The olfactory organ of the skipjack, *Katsuwonus pelamis*. FAO Fish. Rept., 3: 1621–1631, figs. 1–4.

Kleerekoper, H. 1969. Olfaction in fishes. Indiana University Press, Bloomington and London.

Liermann, K. 1933. Über den Bau des Geruchsorgans der Teleostier. Z. Anat. Entwicklung., 100: 1–39, figs. 1–17.

Parker, G. H. and R. E. Sheldon. 1912. The sense of smell in fishes. Bull. U. S. Bur. Fish., 32: 33–46.

Pfeiffer, W. 1963. The morphology of the olfactory organ of the Pacific salmon (*Oncorhynchus*). Canadian J. Zool., 41: 1233–1236, figs. 1–11.

Pfeiffer, W. 1964. The morphology of the olfactory organ of *Hoplopagrus guentheri* Gill. Canadian J. Zool., 42: 235–237, figs. 1–5.

Pfeiffer, W. 1965. The size of the olfactory organ in the burbot, *Lota lota* L. Canadian J. Zool., 43: 223–224, figs. 1–2.

Pipping, M. 1926. Der Geruchssinn der Fische mit besonderer Berücksichtigung seiner Bedeutung für das Aufsuchen des Futters. Soc. Sci. Fennica Commentat. Biol., 2(4): 1–28.

Pipping, M. 1927. Ergänzende Beobachtungen über den Geruchssinn der Fische mit besonderer Berücksichtigung seiner Bedeutung für das Aufsuchen des Futters. Soc. Sci. Fennica Commentat. Biol., 2(9): 1–10.

Teichmann, H. 1954. Vergleichende Untersuchungen an der Nase der Fishe. Z. Morph. Ökol. Tiere, 43: 171–212, figs. 1–31.

Teichmann, H. 1959. Über die Leistung des Geruchssinnes beim Aal (*Anguilla anguilla* L.). Z. Vergl. Physiol., 42: 206–254, figs. 1–10.

Teichmann, H. 1962. Die Chemorezeption der Fische. Ergebn. Biol., 25: 177–205, figs. 1–2.

Van den Berghe, L. 1929. Observations sur l'olfaction et sur le méchanisme des courants olfactifs chez quelques téléostéens. Bull. Acad. Roy. Belg. Sci. Lettr. Beaux Arts, 15: 278–305, figs. 1–10.

Weidersheim, R. 1906. Vergleichende Anatomie der Wirbeltiere. G. Fischer, Jena.

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ウツボの一種 *Muraena undulata* の嗅覚器の解剖と機能

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ウツボの一種，*Muraena undulata* の嗅覚器の解剖を行なった．olfactory rosette は細長く，Burne の rosette column II と，Bateson の rosette type 2 に属する．嗅覚表面は非常に良く発達している．この魚は嗅覚が良く発達し，Teichmann の分類による nose fishes の第3群に属する．

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