such as pH or drug-induced sensitization to current effects (it is possible that drugs alter the threshold of nerve fibres to the excitatory or inhibitory effects of the ejecting currents).

These results obtained with microiontophoretic drug administration contrast with the paucity of axonal effects induced by these drugs when added to the bathing solution. This may be explained by the development of tachyphylaxis, as observed in the present experiments. There are however scattered reports demonstrating in vitro and in vivo axonal effects of acetylcholine[4-6,8-10], catecholamines[4,6,11,12], histamine[4,13,14], and serotonin[4,15]. The axonal receptors for neuroamines display specificity, stereospecificity, and selective blockade by specific blockers[4].

The functional significance of drug sensitive axonal receptors is at present unclear. They may be devoid of function, or they may serve as a target for the action of diffusible neuromodulators (e.g. 2-phenylethylamine) and of exogenous drugs.

Summary. The microiontophoretic administration of putative neuromodulators (acetylcholine, norepinephrine, dopamine, 2-phenylethylamine, tryptamine, histamine) triggered firing or inhibited on-going activity in isolated frog sciatic nerves.

H. C. Sabelli and Joan May[16]

Department of Pharmacology, University of Health
Sciences, The Chicago Medical School and
Department of Anesthesiology Mount Sinai Hospital,
2020 West Ogden Avenue, Chicago (Illinois 60612, USA),
14 April 1975.

---

[8] C. J. Armett and J. M. Ritchie, J. Physiol., Lond. *155*, 372 (1961).

[9] J. E. P. Toman and H. C. Sabelli, Int. J. Neuropharmac. *7*, 543 (1968).

[10] H. W. Kosterlitz, G. M. Lees and D. I. Wallis, J. Physiol., Lond. *195*, 39 (1968).

[11] W. Haefely, *Catecholamines* (Eds. H. Blaschko and E. Muscholl; Springer-Verlag, Heidelberg-New York 1972).

[12] M. Goffart and O. Holmes, J. Physiol., Lond. *162*, 18 (1962).

[13] E. Baranz and P. Nordqvist, Nature, Lond. *164*, 701 (1949).

[14] M. Scuka, Neuropharmacology *12*, 441 (1973).

[15] V. Dicarlo, *Progress in Brain Research* (Eds. H. E. Himwich and W. A. Himwich;Elsevier, Amsterdam 1964), vol. 8.

[16] This research was supported by the National Institute of Mental Health (grant No. MH-14110) and by the Anesthesiology Research Fund. The authors wish to thank Dr. H. H. Havdala for his encouragement and collaboration, and Ms. Anna Maslanka and Ms. Linda Wilson for excellent technical assistance.

The Anterior Cranial Gustatory Pathway in Fish

It has long been known that the lips of fish are supplied by cranial nerves V (trigeminal) and VII (facial), and that taste buds on the lips or barbels are innervated by the latter[1,2]. Recent investigations on the peripheral neural response of fish seem to support the innervation of taste buds by the VIIth nerve[3-5]. Yet, investigations with higher vertebrates suggest that the trigeminus is also involved in the transmission of taste messages[6,7]. Little attention, however, seems to have been given to the functional difference between the trigeminal and facial nerves in fish[8].

In this paper, an attempt was made to throw light on the gustatory neural pathway of fish from the lips to the

---

[1] C. J. Herrick, J. comp. Neurol. *9*, 153 (1899).

[2] C. J. Herrick, J. comp. Neurol. *11*, 177 (1901).

[3] J. E. Bardach, M. Fujiya and A. Holl, in *Olfaction and Taste II* (Ed. T. Hayashi; Pergamon Press, Oxford and New York 1967), p. 647.

[4] J. Konishi, M. Uchida and Y. Mori, Jap. J. Physiol. *16*, 194 (1966).

[5] H. Tateda, Nature, Lond. *192*, 343 (1961).

[6] G. Hellekant, in *Olfaction and Taste II* (Ed. T. Hayashi; Pergamon Press, Oxford and New York 1967), p. 465.

[7] Y. Kawamura, J. Okamoto and M. Funakoshi, Physiol. Behav. *3*, 537 (1968).

[8] A. M. Sutterlin and N. Sutterlin, J. Fish. Res. Bd. Can. *27*, 1927 (1970).

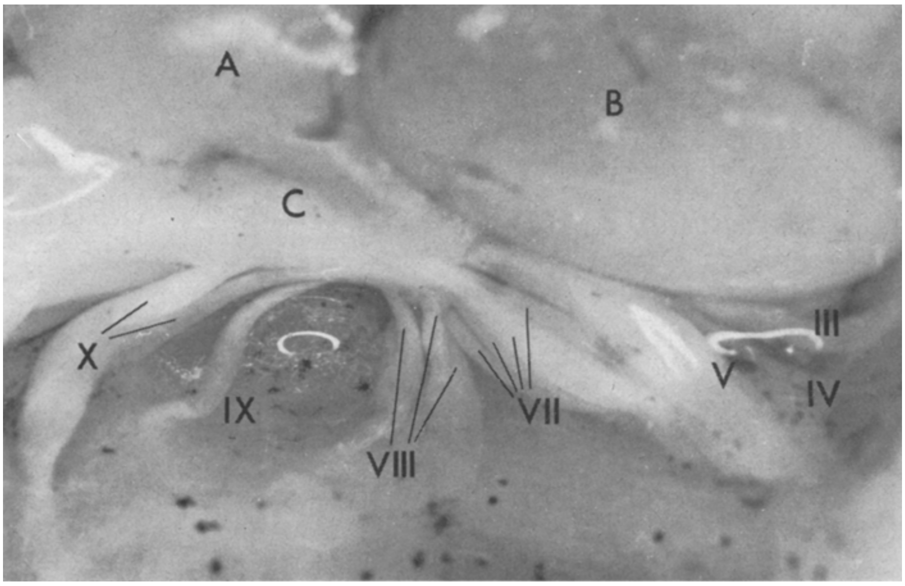

Fig. 1a) Lateral view of the brain and cranial nerves of the puffer. A, cerebellum; B, midbrain; C, medulla oblongata; III, oculomotor nerve; IV, trochlear nerve; V, trigeminal nerve; VII, facial nerve; VIII, vestibular nerve; IX, glossopharyngeal nerve; X, vagus nerve.

brain, using electrophysiological methods. The results support the view that taste messages from the lips are transmitted by the facial nerve only.

In fish, the Vth and VIIth nerve components are so intimately united peripherally[1,2] that it is generally difficult to discriminate one from the other. Therefore, we attempted to record the neural activity from inside the cranium.

Puffer, *Fugu pardalis*, were used. They were anesthetized by placing them in 0.002% MS 222 or 0.001% 4-allyl-2-methoxyphenol for 5 min. The skull roof was opened and mesenchymal tissues were removed under a dissecting microscope to expose the Vth and VIIth nerves. In this fish, shortly after the trigemino-facial complex trunk enters the cranium, each of the two nerve components runs separately toward a different center. At this point, a complete identification of each component was possible. The facial nerve comprises 4 groups of fibres, each running separately into the brain (Figure 1a). These 4 roots of the facialis are referred to as communis, dorsal lateralis, ventral lateralis, and motor by HERRICK[1]. Using a specimen weighing about 50 g, the electrical activity of each of these bundles could be recorded by inserting an electrode into the cranium, although technically this recording is more difficult than a peripheral one. The topographical arrangement of the Vth and VIIth nerves in the head region is illustrated in Figure 1b. Both ramus maxillaris and ramus mandibularis, innervating the upper and lower lip respectively, receive fibres from the trigeminus and communis simultaneously. The other components of the facial nerve do not innervate the lips.

To record from inside the cranium solely the activity of the fibres innervating the upper lip, the ramus palatinus, which receives fibres from the communis and innervates the roof of the mouth, and the ramus mandibularis were cut under the eye. The nerve bundle was hooked on a platinum wire electrode, an indifferent electrode being attached on the skull. The nerve activity was amplified, displayed on a cathode-ray oscilloscope and integrated with an electric integrator. NaCl, NaSCN, HCl, proline and UMP (uridine-5′-monophosphate) which proved to be effective on the lip chemoreceptors of the puffer[9,10], were employed as taste stimuli. The salts were dissolved in distilled water and the other substances were dissolved in artificial sea water. The taste solutions were poured over the lip surface from a specially made funnel with a cock. During experiments, the gills were irrigated with sea water.

Afferent fibres of the communis were found to respond to all of the taste solutions, while those of the trigeminus did not respond to any of them, except for salts at extraordinarily high concentrations. Figure 2 shows the nerve discharges from the communis and trigeminus and their integrated patterns upon application of various taste solutions to the upper lip. Sea water elicited a positive response in both nerve preparations. However, this response may be attributed to a mechanical stimulus caused by the process of applying sea water. In the trigeminal nerve preparation, the magnitude and temporal pattern of each of the integrated responses to test solutions are quite similar to those for sea water or touch. This suggests that these trigeminal responses are also due to the mechanical stimuli. In the communis nerve preparation, in contrast, the integrated response to each

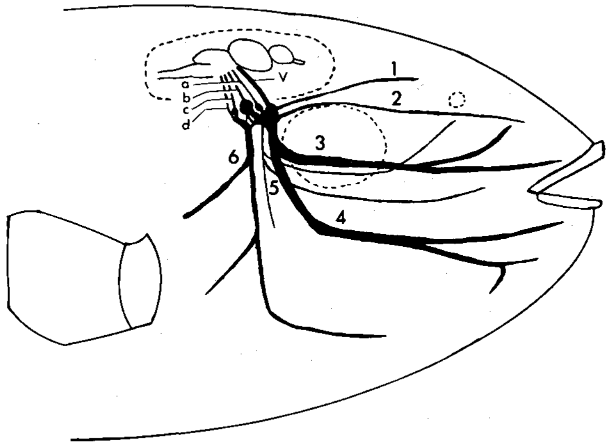

Fig. 1b) Major branches of the Vth and VIIth nerves as projected on the right side of the puffer. V, trigeminal nerve; a, dorsal lateralis root of VII; b, communis root of VII; c, ventral lateralis root of VII; d, motor root of VII; 1, ramus opthalmicus superficialis (VII); 2, ramus palatinus facialis; 3, ramus maxillaris (V + VII); 4, ramus mandibularis (V + VII); 5, ramus buccalis facialis; 6, ramus hyomandibularis (V + VII).

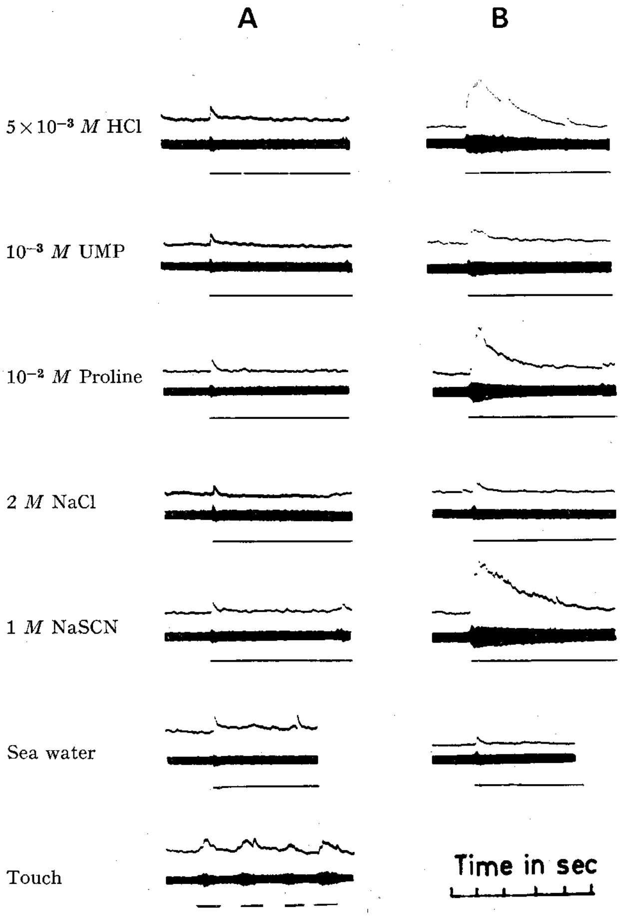

Fig. 2. Neural activity of A) trigeminal and B) communis nerves in response to stimulation of the upper lip of the puffer. Impulse discharges (lower trace) and their integrated patterns (upper trace) are shown. Bar under each recording indicates duration of stimulation. Test solutions: from top to bottom, 5×10^{-3} *M* uridine-5′-monophosphate, 10^{-2} *M* proline, 2 *M* NaCl, 1 *M* NaSCN, sea water and touch. Data were obtained from a single specimen.

---

[9] I. HIDAKA, S. KIYOHARA, M. TABATA and K. K. YONEZAWA, Bull. Jap. Soc. Sci. Fish. *41*, 275 (1975).

[10] S. KIYOHARA, I. HIDAKA and T. TAMURA, Bull. Jap. Soc. Fish. *41*, 383 (1975).

of HCl, UMP, proline, NaCl and NaSCN exceeds in magnitude that to sea water. Also, the nerve discharges elicited by these active taste solutions lasted for 1.5 sec or more after beginning of stimulation while the reaction to sea water ceased within 0.5 sec. The responses obtained here with these taste solutions were similar in every respect to those recorded more peripherally from the ramus maxillaris of the puffer, as seen from Figure 3. Detailed data dealing with the latter were reported elsewhere[9,10]. The results mentioned above suggest that the taste message from the upper lip of the puffer to the brain is transmitted by the communis fibres.

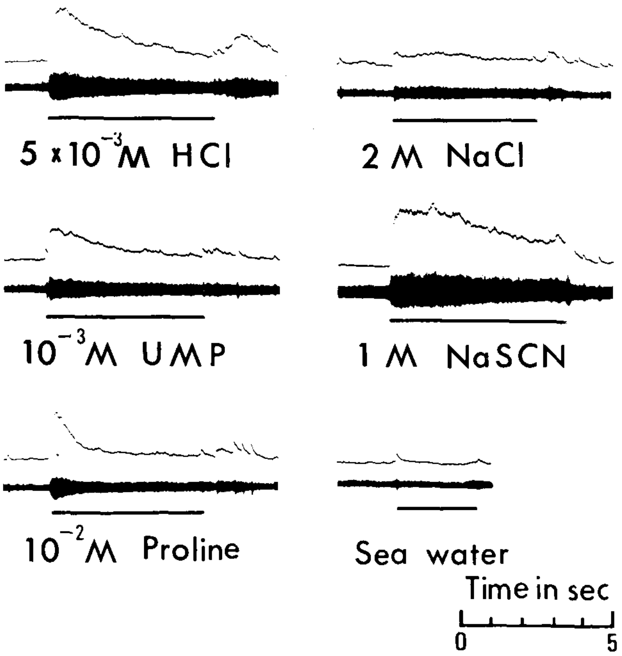

Fig. 3. Neural activity of ramus maxillaris in response to stimulation of the upper lip of the puffer. Impulse discharges (lower trace) and their integrated patterns (upper trace) are shown. Bar under each recording indicates duration of stimulation.

The trigeminus responded neither to 2 M NaCl nor to 1 *M* NaSCN, while the communis appeared to be responsive to both the salts solutions (Figure 2). Still, the trigeminus was found to be responsive to NaSCN at high concentrations such as 3 *M* or more. Similar responses to salts have been recorded from the lingual nerve (trigeminal) innervating the tongue of the rat[7]. In this case also, the threshold concentration for NaCl is several times higher than that of the chorda tympani (facial). In the puffer, it was also noted that the response to NaSCN developed more slowly than the responses of the communis to other taste solutions, and the response to NaSCN lasted for a long period after rinsing of the lip with sea water, causing irreversible damage to the preparations.

From the fact that no responses could be obtained inside the cranium from the trigeminus upon applying taste solutions to the lower lip, while positive responses were obtained from the mandibularis, it was concluded that communis fibres (i.e. facial nerve) are involved also in the transmission of taste messages from the lower lip.

Zusammenfassung. Mit Hilfe elektrophysiologischer Methodik wurde an *Fugu pardalis* geprüft, ob Geschmackssensationen von den Lippen über Trigeminus- oder Facialisfasern dem Gehirn übermittelt werden. Die Ergebnisse unterstützen die Ansicht, dass ausschliesslich der Facialisnerv bei diesem Vorgang beteiligt ist.

S. Kiyohara, I. Hidaka[11] and
T. Tamura[12]

Fisheries Laboratory, Faculty of Agriculture,
Nagoya University, Nagoya (Japan); and
Faculty of Fisheries, Mie University,
Tsu, Mie (Japan), 29 April 1975.

---

[11] Faculty of Fisheries, Mie University, Tsu, Mie (Japan).

[12] The authors wish to thank Director John E. Bardach, University of Hawaii, for critical reading of the manuscript. This work was supported in part by Science Research Grants, Nos. 811009 and 848046 from the Ministry of Education of Japan.

Tendon Shortening in Striated Muscle

The adaptive response of oral striated muscle to a maintained stretch has important implications to dental practitioners. The length of oral muscles may changes as a result of dental restorative or orthodontic treatment procedures. Growth of bony parts also is accompanied by an increase in the length of associated muscles. However, only a few studies have attempted to deal with the adaptive response of skeletal muscle to maintained changes in length. The functional properties of rabbit limb muscles were shown by Crawford[1] to change directly with an increase or decrease in range of motion of the limb. Goldspink[2] demonstrated a reversible change in the number of serial sarcomeres in cat soleus muscle corresponding to a maintained increase or decrease in passive muscle tension. Shortening of the tendon of rat limb muscle by Schiaffino[3] resulted in only a temporary change in muscle length and sarcomere length. The present study describes changes in muscle belly length, tendon length, and muscle sarcomere length resulting from shortening of the tendon of an oral striated muscle.

Material and methods. The digastric (mandibular) muscle of the mature male, New Zealand white rabbit was the model of an oral muscle selected for this study. The paired digastric muscle has a simple fibre arrangement and a long, flat tendon. The tendon was shortened by tying a portion of it into a loop with black silk suture. Changes in muscle belly length and tendon length were observed in this chronic study by measuring the distance between metal markers that were implanted in the muscle and tendon. The markers were visualized with radiographs taken periodically. Details of the technique for placing, radiographing, and measuring the distance between the metal markers have been reported elsewhere[4]. Histologic slides were prepared of digastric muscles from

---

[1] G. N. C. Crawford, J. Anat. *111*, 143 (1972).

[2] G. Goldspink, C. Tabary, J. C. Tabary, C. Tardieu and G. Tardieu, J. Physiol., Lond. *236*, 733 (1974).

[3] S. Schiaffino, Experientia *30*, 1163 (1974).

[4] Z. F. Muhl and A. F. Grimm, Arch. oral Biol. *19*, 829 (1974).