UC Irvine

UC Irvine Previously Published Works

Title

Different distribution of serotonin in an elasmobranch (*Scyliorhinus stellaris*) and in a teleost (*Conger conger*) fish.

Permalink

<https://escholarship.org/uc/item/726160mv>

Journal

Comparative biochemistry and physiology. C, Comparative pharmacology and toxicology, 74(1)

ISSN

0742-8413

Authors

Piomelli, D
Tota, B

Publication Date

1983

DOI

10.1016/0742-8413(83)90165-2

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at
<https://creativecommons.org/licenses/by/4.0/>

Peer reviewed

DIFFERENT DISTRIBUTION OF SEROTONIN IN AN ELASMOBRANCH (*SCYLIORHINUS STELLARIS*) AND IN A TELEOST (*CONGER CONGER*) FISH

D. PIOMELLI and B. TOTA*

Institute of Experimental Pharmacology, Faculty of Pharmacy, University of Naples, and
Zoological Station of Naples, Naples, Italy

(Received 22 April 1982)

Abstract—1. A comparative quantitative study on the occurrence of 5-HT in several tissues and organs of the elasmobranch *Scyliorhinus stellaris* and the teleost *Conger conger* has been carried out.

2. In *Scyliorhinus*, the richest source of the amine is the brain, in which 5-HT is twice as concentrated as in the teleost brain. Significant levels have been also detected in the intestine, followed by gills and heart. 5-HT is also concentrated in other epithelial organs, such as the rectal gland and the olfactory organ.

3. In *Conger*, the gills show the highest content of 5-HT, in which, like in the kidney, serotonin is 2–3 times more concentrated than in the corresponding organs of the elasmobranch.

4. These differences are discussed in relation to the distinct phylogenetic and ecophysiological features of the two animals. In addition, the possible functional significance of 5-HT in the fish heart is taken into consideration.

INTRODUCTION

The literature concerning the occurrence and function of serotonin (5-HT) in lower vertebrates, and particularly in fish, is sparse. In fact, while some quantitative data from the gastrointestinal tract (Erspamer, 1953) as well as from the nervous system (Correale, 1956; Bogdanski *et al.*, 1963; Brodie *et al.*, 1964) are reported and have been related to the well-known neurohumoral function of this amine, there is still a lack of knowledge on the content and function of 5-HT in other piscine organs and tissues. Such a lack is particularly acute considering the multiple role of 5-HT, as indicated by the long phylogenetic history of this substance, which has been firmly recognized (see e.g. Haber *et al.*, 1981, for references).

The present comparative work was carried out on an elasmobranch (*Scyliorhinus stellaris*) and on a teleost (*Conger conger*) marine fish for providing some preliminary quantitative information concerning the occurrence of 5-HT in those still undetected tissues and organs in which a multiple function of this agent can be inferred.

MATERIALS AND METHODS

Scyliorhinus stellaris and *Conger conger*, weighing between 700 and 1300 g, were obtained during the autumn and the winter from the aquarium of the Zoological Station of Naples, where they were kept in holding tanks with circulating sea water at 16–18°C for at least 10 days. The animals were killed by decerebration. The blood was collected by a syringe inserted into the ventricle, after exposure of the heart by opening the ventral body wall. The

myotomal muscles were dissected from the caudal end of the body. The gill filaments were clipped with surgical scissors from the arches. All organs were immediately weighed after excision from the fish.

Extraction of 5-HT

The extraction was performed according to the method of Welsh & Moorhead (1960). HCl (1 N) was added to the tissue (w/v = 1:2); the tissue, minced with scissors, was then homogenized with further addition of distilled water (HCl: water = 1:2). The homogenates were boiled for 1–2 min and centrifuged at low speed (5000 g for 10 min).

The supernatants were collected and neutralized with 1 N NaOH. Preliminary experiments based on the extraction of known amounts of 5-HT have shown a recovery of the amine varying between 80 and 85%, a value rather close to that reported by Welsh (1964).

Bioassay of 5-HT

The bioassay method employed in this work was that reported by Vane (1957) on a strip of fundus from a rat stomach. This is a very sensitive method, allowing the detection of such low amounts of 5-HT as 50 pg or 1 ng. Prior to this, the samples were incubated with small amounts of Tyrosinase (Sigma) for destroying selectively all the sympathomimetic amines that can interfere with the bioassay of 5-HT. Atropine (20 µg/l) was added to the bathing Krebs solution.

RESULTS AND DISCUSSION

The data obtained in the two marine fishes are reported in Fig. 1. A comparison can be made with the values reported in Table 1, where most of the quantitative information on the occurrence of 5-HT in poikilothermic vertebrates has been tabulated. On the basis of such a survey, our data fall within the range of values reported in lower vertebrates. It is clear that in the two fishes the organ distribution of

* Requests for reprints should be sent to: Prof. Bruno Tota, Istituto di Farmacologia Sperimentale, Facoltà di Farmacia, via L. Rodinò 22, 80138 Napoli, Italy.

Fig. 1. Concentration of serotonin in several tissues of *Scyllium* and *Conger*, in parenthesis: number of animals examined; vertical bars: $\pm$ SE.

the amine differs significantly. In fact, the elasmobranch brain has approximately more than a double amount of 5-HT than the teleost brain. In contrast, compared to the elasmobranch, *Conger conger* exhibits a higher content of 5-HT in its gills (where the amine is almost three times more concentrated than in the elasmobranch gills), spleen and kidney.

The different encephalic content of 5-HT in *Scyllium* and *Conger* is of particular interest, since these are two phylogenetically distant fishes and are also characterized by distinct ecophysiological habits. Indeed, a comparative survey of the morphological organization of 5-HT neuronal systems in the brain of lower vertebrates (Parent, 1981) indicates that at this level differences can probably occur in several groups of fishes. On the other hand, in addition to this, the multiple localization of 5-HT in the fish brain includes also other morphological and functional compartments, such as the pineal, the neuroendocrine output of melatonin, and the ependymal cells. Thus, the physiological significance of this difference, revealed on the basis of a whole organ analysis, requires further zonal study in order to be better elucidated.

The finding of the highest content of serotonin in the gill filaments of *Conger conger* is consistent with an intrinsic role of this amine either in the branchial microcirculation or in the epithelial transport, or in both.

Important differences in the functional anatomy of the branchial microvasculature, as well as in the role of the corresponding nerve supply and humoral modulation, have been recently surveyed in several teleosts (including *Anguilla*) and elasmobranchs (including *Scyliorhinus*) by Dunel & Laurent (1980). Pharmacological experiments *in vivo* in the trout *Salmo gairdneri* have led Thomas *et al.* (1979) to suppose that serotonin plays a major role in the adjustment of the branchial circulation and particularly of the lamellar perfusion. On the other hand, the dramatic differences in gill permeability and osmoregulation between teleosts and elasmobranchs very likely reflect a different humoral endowment of the gill fila-

ments epithelium. Such a role of 5-HT is strongly supported by our results.

The fact that 5-HT levels in *Conger* kidney are three times those in elasmobranch kidney could be related to the higher levels of excretion and osmoregulation characteristic of the "teleost machine" in comparison with the elasmobranch. This is in agreement both with the direct regulatory role of 5-HT postulated by Erspamer & Ottolenghi (1952a,b) on mammalian kidney function, and with the results of Welsh & Moorhead (1960) who found in a number of invertebrates relatively high levels of 5-HT in poorly innervated excretory organs, including kidney. In the light of this, the relatively high content of the amine in other epithelial tissues such as the rectal gland and the olfactory organ of *Scyliorhinus*, involved in salt transport and chemosensory functions, respectively, indicates additional organ models for providing an insight into the role of serotonin in epithelial physiology.

In both fishes, the heart has remarkable amounts of 5-HT. While the role of serotonin on invertebrate heart has been to some extent investigated (Erspamer & Ghirelli, 1951; Kiss & Rozsa, 1978), its role in the vertebrate heart remains still obscure.

The cardiac chambers of the elasmobranchs (Saetersdal *et al.*, 1975; Berge, 1979) and teleosts (Lamanski *et al.*, 1975; Midttun, 1981) are characterized by remarkable amounts of granule-containing cells, often located just beneath the endocardium. Such a topological condition is strategically suited for releasing pharmacologically active substances directly into the cardiac lumen. On the other hand, compared to that of higher vertebrates, the fish heart is endowed with a very high catecholamine content that exerts important effects upon the myocardial function and marked vasodilator action on the branchial circulation (Fänge, 1962; Satchell, 1971). The well-known vasoconstriction effect of 5-HT, together with the significant amount of the amine in the hearts of the two fishes, might well be related to the maintenance of vascular control in these animals. Moreover, the fact that 5-HT may release noradrenaline from several

Table 1. The 5-HT content of various tissues of poikilotherm vertebrates (μg 5-HT/g fresh tissue)

Species	Brain	Blood	Spleen	Gastro-intestinal tract	Gills	Lungs	Kidney	Bladder	Muscle	Author
Cyclostomes										
<i>Petromyzon planeri</i>		<0.05		0.2						Erspamer (1954)
<i>Petromyzon marinus</i>		<0.03								Erspamer (1954)
Fishes										
<i>Scyliorhinus canicula</i>	0.2	<0.02	0.06	2.6						Correale (1956); Erspamer (1954)
<i>Scyliorhinus stellaris</i>		<0.04	0.06	2.3						Erspamer (1954)
<i>Torpedo marmorata</i>		<0.02	<0.06	2.5						Erspamer (1954)
<i>Amblyraja</i>	0.48			1.2						Brodie <i>et al.</i> (1964)
<i>Arcipenser naccarii</i>		0.01	0.03	0.34						Erspamer (1954)
<i>Arcipenser sturio</i>		0.025	0.03	0.38						Erspamer (1954)
<i>Ameiurus catus</i>		<0.05		0.2-0.4(?)						Erspamer (1954)
<i>Ameiurus nebulosus</i>		0.02	0.12	0.15-0.74			0.04			Welsh (1964)
<i>Anguilla anguilla</i>		<0.05	<0.05	<0.2-0.4(?)						Erspamer (1954)
<i>Tinca tinca</i>		0.04	0.05	<0.2 0.4(?)						Erspamer (1954)
<i>Carassius auratus</i>	0.15			1.1						Brodie <i>et al.</i> (1964)
<i>Thunnus thynnus</i>	0.2									Correale (1956)
Amphibia										
<i>Rana esculenta</i>		0.18								Erspamer (1954)
<i>Rana pipiens</i>	3.7	0.17-0.23		1.4-5.4		0.18		0.56		Bogdanski <i>et al.</i> (1963); Welsh (1964)
<i>Rana catesbeiana</i>		0.01	0.08	1.9 4.2		0.03		0.04	0.01	Bogdanski <i>et al.</i> (1963)
<i>Hyla cinerea</i>	2.0			4.8						Bogdanski <i>et al.</i> (1963)
<i>Bufo bufo bufo</i>		0.02		1.6						Erspamer (1954)
<i>Bufo americanus</i>	9.1			5.1						Bogdanski <i>et al.</i> (1963)
<i>Bufo marinus</i>	1.5			5.1						Bogdanski <i>et al.</i> (1963)
<i>Bufo arenarum</i>	0.8-1.3			1.5						Nobili (quoted by Erspamer, 1966)
<i>Desmognathus fuscus</i>	2.8			5.0						Bogdanski <i>et al.</i> (1963)
<i>Ambystoma tigrinum</i>	2.9			2.1						Bogdanski <i>et al.</i> (1963)
<i>Necturus maculosus</i>	1.1	0.05 0.2		0.26-0.86		0.26 0.81		0.18 0.26	0.04	Welsh (1964)
Reptiles										
<i>Alligator mississippiensis</i>	0.21 1.56									Welsh (1964)
<i>Testudo graeca</i>		0.01	0.01	3.2						Erspamer (1954)
<i>Sceloporus cyanogenis</i>	3.1									Bogdanski <i>et al.</i> (1963)

tissues (for references see Marin *et al.*, 1981) should prompt further studies on a putative control of serotonin on the mechanism of cardiac secretion of catecholamines in fishes. On the whole, these data shed more light on the concept of the fish heart as an "endocrine" organ.

REFERENCES

- BERGE P. I. (1979) The cardiac ultrastructure of *Chimaera monstrosa* L. (Elasmobranchii: Holocephali). *Cell. Tiss. Res.* **201**, 181–195.
- BOGDANSKI D. F., BONOMI L. & BRODIE B. B. (1963) Occurrence of serotonin and catecholamines in brain and peripheral organs of various vertebrate classes. *Life Sci.* **1**, 80–84.
- BRODIE B. B., BOGDANSKI D. F. & BONOMI L. (1964) Formation, storage and metabolism of serotonin and catecholamines in lower vertebrates. In *Comparative Neurochemistry* (Edited by RICHTER D.), pp. 367–377. Pergamon Press, Oxford.
- CORREALE P. (1956) The occurrence and distribution of 5-hydroxytryptamine in the central nervous system of vertebrates. *J. Neurochem.* **1**, 22–31.
- ERSPAMER V. & GHIRETTI F. (1951) Action of enteramine on heart of molluscs. *J. Physiol.* **115**, 470–481.
- ERSPAMER V. & OTTOLENGHI A. (1952a) Antidiuretic action of small doses of enteramine extracts in the rat. *Experientia* **8**, 31–33.
- ERSPAMER V. & OTTOLENGHI A. (1952b) Antidiuretic action of pure synthetic enteramine in hydrated rats. *Experientia* **8**, 232–233.
- ERSPAMER V. (1953) Über den 5-Hydroxytryptamine Gehalt des Magen-Darmtraktes bei den Wirbeltieren. *Naturwissenschaften* **11**, 318–319.
- ERSPAMER V. (1954) Pharmacology of indolealkylamines. *Pharmac. Rev.* **6**, 425–487.
- ERSPAMER V. (1966) 5-Hydroxytryptamine and related indolealkylamines. In *Handbook of Experimental Pharmacology* Vol. 19 (Edited by ERSPAMER V.), pp. 132–166. Springer, Berlin.
- FÄNGE R. (1962) Pharmacology of poikilothermic vertebrates and invertebrates. *Pharmac. Rev.* **14**, 281–316.
- HABER B., GABAY S., ISSIDORIDES M. R. & ALIVISATOS S. G. A. (1981) *Serotonin: Current Aspects of Neurochemistry and Function*. *Adv. exp. Med. Biol.*, Vol. 133. Plenum Press, New York.
- KISS T. & ROZSA K. S. (1978) Pharmacological properties of 5-HT receptors of the *Helix pomatia* L. (Gastropoda) heart muscle cells. *Comp. Biochem. Physiol.* **61C**, 41–46.
- LEMANSKI L. F., PAYSON FITTS E. & MARX B. S. (1975) Fine structure of the heart in the Japanese Medaka, *Oryzias latipes*. *J. Ultrastruct. Res.* **53**, 37–65.
- MARIN J., ARIAS M., SALAICES M., SANCHEZ C. F. & RECIO L. (1981) Vasoconstrictor effects of serotonin in the isolated superior mesenteric artery of cat. *Gen. Pharmac.* **12**, 97–101.
- MIDTTUN B. (1981) Ultrastructure of atrial and ventricular endocardium and cardiac capillary endothelium of the pike. *Tiss. Cell* **13**, 747–756.
- PARENT A. (1981) Comparative anatomy of the serotoninergic system. *J. Physiol., Paris* **77**, 147–156.
- SAETERSDAL T. S., SORENSEN E., MYKLEBUST R. & HELLE K. B. (1975) Granule-containing cells and fibers in the sinus venosus of elasmobranchs. *Cell Tiss. Res.* **163**, 471–490.
- SATCHELL G. H. (1971) *Circulation in Fishes*. Cambridge University Press, Cambridge.
- THOMAS S., BELANUD A. & PEIRAUD C. (1979) Arguments for serotonergic adjustments in gill blood circulation in fish. *IRCS Medic. Sci. (France)* **7**, 543.
- VANE J. R. (1957) A sensitive method for the assay of 5-hydroxytryptamine. *Br. J. Pharmac.* **12**, 344–349.
- WELSH J. H. (1964) The quantitative distribution of 5-HT in the nervous system, eyes and other organs of some vertebrates. In *Comparative Neurochemistry* (Edited by RICHTER D.), pp. 355–366. Pergamon Press, Oxford.
- WELSH J. H. & MOORHEAD M. (1960) The quantitative distribution of 5-HT in the invertebrates, especially in their nervous systems. *J. Neurochem.* **6**, 146–169.