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

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(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.

The extraction was performed according to the method of Welsh & Moorhead (1960).

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 I, 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
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 bronchial microcirculation or in the epithelial transport, or in both.

Important differences in the functional anatomy of the branchial microcirculation, as well as in the role of the corresponding nerve supply and humoral modulation, have been recently surveyed in several teleosts (including Ayuillu and elasmobranches including Scyllorhinus) by Dunez & Laurent (1980). Pharmacological experiments in vivo in the trout Salmo gairdnerii 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 elasmobranches very likely reflect a different humoral endowment of the gill filaments 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 5-HT in its gills (where the amine is almost three times more concentrated than in the elasmobranch gills). spleen and kidney.

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 & Ghiretti, 1951; Kiss & Rozsa, 1978), its role in the vertebrate heart remains still obscure.

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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 | Gill | Lung | Kidney | Bladder | Muscle | Author                          |
|---------------------------|-------|-------|--------|--------------------------|------|------|--------|---------|--------|---------------------------------|
| **Cyclostomes**           |       |       |        |                          |      |      |        |         |        |                                 |
| Petromyzon planeri        | < 0.05|       |        | 0.2                      |      |      |        |         |        | Erspermer (1954)                |
| Petromyzon marinus        | < 0.03|       |        |                          |      |      |        |         |        | Erspermer (1954)                |
| **Fishes**                |       |       |        |                          |      |      |        |         |        |                                 |
| Scyliorhinus canicula     | 0.2   | < 0.02| 0.06   | 2.6                      |      |      |        |         |        | Correale (1956); Erspermer (1954) |
| Scyliorhinus stellaris    | < 0.04| 0.06  | 2.3    |                          |      |      |        |         |        | Erspermer (1954)                |
| Torpedo marmorata         | < 0.02| < 0.06| 2.5    |                          |      |      |        |         |        | Erspermer (1954)                |
| Anguilla anguilla         | 0.48  |       |        | 1.2                      |      |      |        |         |        | Brodie et al. (1964)            |
| Anguilla acutissima       | 0.01  | 0.03  | 0.34   |                          |      |      |        |         |        | Erspermer (1954)                |
| Anguilla oxycephala       | 0.025 | 0.03  | 0.38   |                          |      |      |        |         |        | Erspermer (1954)                |
| Anguilla marmorata        | < 0.05|       |        | 0.2-0.4(?)               |      |      |        |         |        | Erspermer (1954)                |
| Anguilla japonica         | < 0.05| < 0.05| < 0.2-0.4(?) |            |      |      |        |         |        | Welsh (1964)                    |
| Tinca tinca              | 0.04  | 0.05  | < 0.2 0.4(?) |            |      |      |        |         |        | Erspermer (1954)                |
| Curassios auratus         | 0.15  |       |        | 1.1                      |      |      |        |         |        | Brodie et al. (1964)            |
| Thunnus thynnus          | 0.2   |       |        |                          |      |      |        |         |        | Correale (1956)                 |
| **Amphibia**              |       |       |        |                          |      |      |        |         |        |                                 |
| Rana esculenta            |       |       |        |                          | 0.18 |      |        |         |        | Erspermer (1954)                |
| Rana pipiens              | 3.7   | 0.17-0.23| 1.4-5.4 |                        | 0.18 | 0.26 |        |         |        | Bogdanski et al. (1963); Welsh (1964) |
| Rana catesbeiana          | 0.01  | 0.08  | 1.9 4.2 |                        | 0.03 | 0.04 | 0.01  |         |        | Bogdanski et al. (1963)         |
| Hyla cinerea              | 2.0   |       |        |                          |      |      |        |         |        | Bogdanski et al. (1963)         |
| Bufo bufo bufo           | 0.02  |       |        |                          |      |      |        |         |        | Erspermer (1954)                |
| Bufo americanus           | 9.1   |       |        |                          |      |      |        |         |        | Bogdanski et al. (1963)         |
| Bufo marinus              | 1.5   |       |        |                          |      |      |        |         |        | Erspermer (1954)                |
| Bufo arenarum             | 0.8-1 1 |       |        |                          |      |      |        |         |        | Bogdanski et al. (1963)         |
| Desmognathus fuscus       | 2.8   |       |        |                          |      |      |        |         |        | Nobili (quoted by Erspermer, 1966) |
| Ambystoma tigrinum        | 2.9   |       |        |                          |      |      |        |         |        | Bogdanski et al. (1963)         |
| Necturus maculosus        | 1.1   | 0.05  | 0.2 0.26-0.86 |                            | 0.26 | 0.26 | 0.18  | 0.26 | 0.04 | Welsh (1964)                   |
| **Reptiles**              |       |       |        |                          |      |      |        |         |        |                                 |
| Alligator mississippiensis| 0.21  | 1.56  |        |                          |      |      |        |         |        | Welsh (1964)                    |
| Testudo graeca            |       | 0.01  | 0.01  |                          |      |      |        |         |        | Erspermer (1954)                |
| Sceloporus cyphophisius   | 3.1   |       |        |                          |      |      |        |         |        | Bogdanski et al. (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

Berger P. I. (1979) The cardiac ultrastructure of *Chaetodermus* L. (Elaeombranchii: Holostei). *Cell. Tiss. Res.* 201, 181-195.

Bogdański D. F., Bonomi L. & Brodie B. B. (1963) Occurrence of serotonin and catecholamines in brain and peripheral organs of various vertebrate classes. *J. Sci.* 1, 80-81.

Brodie B. B., Bogdański 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, 470-485.

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-Hydroxytryptaminkalial des Magen-Darmtraktes bei den Wirbeltieren. *Naturwissenschaften* 11, 318-319.

ERSPAMER V. (1954) Pharmacology of indolealkylamines. *Pharmacol. Rev.* 6, 425-487.

ERSPAMER V. (1966) 5-Hydroxytryptamine and related indolealkylamines. In *Handbook of Experimental Pharmacology* Vol. 19 (Edited by ERSAMER V.), pp. 132-166, Springer, Berlin.

FANG R. (1962) Pharmacology of poikilothermic vertebrates and invertebrates. *Pharmacol. Rev.* 14, 281-310.

HABER B., GABAY S., ISHDORJIN M. R. & AKIVISSIAN 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., Saluces M., Sanchez C. F. & RICO L. (1981) Vasoconstrictor effects of serotonin in the isolated superior mesenteric artery of cat. *Gen Pharmacol.* 17, 97-101.

MIDDDD B. (1981) Ultrastructure of atrial and ventricular endocardium and cardiac capillary endothelium of the pig. *Tiss. Cell* 13, 747-756.

PARENT A. (1981) Comparative anatomy of the serotoninergic system. *J. Physiol., Paris* 77, 147-156.

SCHRÖDL T. S., SØRENSEN E., MØKKlesen R. & HELF 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., BELAND A. & PERAUD C. (1979) Arguments for serotoninergic adjustments in gill blood circulation in fish. *IRCS Med. Sci. (France)* 7, 543.

VAN J. J. R. (1957) A sensitive method for the assay of 5-hydroxytryptamine. *Br. J. Pharmacol.* 12, 344-349.

WEIL 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.

WEIL J. H. & MOORHEAD M. (1960) The quantitative distribution of 5-HT in the invertebrates, especially in their nervous systems. *J. Neurochem.* 6, 146-169.