STUDIES ON THE ADRENAL GLANDS OF TELEOSTS—III*.
ON THE DISTRIBUTION OF CHROMAFFIN CELLS AND INTERRENAL
CELLS IN THE HEAD KIDNEYS OF FISHES

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Adrenal glands are important endocrine organs and in mammals it is ascertained that the adrenal cortex is necessary for the regulation of certain aspects of water, mineral and carbohydrate metabolism, and for releasing of immune bodies. It is accordingly supposed that the adrenal glands of teleosts may be also related to such important functions. However, these functions in teleosts have unsatisfactorily been elucidated. On the adrenal glands of Japanese teleosts no studies, except authors', were reported. In this paper, the histological observations on the adrenal glands of ten species of teleosts are recorded, as a continuation of the results obtained in the previous papers^{1), 2)}.

The mammalian adrenal glands consist of medulla and cortex. However, in teleosts the cells corresponding to the medullary cells of adrenal glands are called the chromaffin cells and appear in the head kidneys³⁾. As for the organs homologous to the mammalian adrenal cortex in teleosts, two organs, i.e. the groups of acidophile cells in the head kidneys and the corpuscles of STANNIUS, have long been described and the former organ has been named "anterior interrenal" and the latter "posterior interrenal"⁴⁾. The groups of acidophile cells surround the cardinal veins and their branches in the lymphoid head kidneys. On the other hand, the corpuscles of STANNIUS are located on or embedded in the dorsal or ventral surface of the kidneys. Histologically, the cells composing these corpuscles are remarkably different from the acidophile cells^{1), 2)}.

Embryologically, the acidophile cells in teleosts arise from the coelomic mesoderm and also have the same developmental origin as the cortical cells of mammals⁵⁾. On the other hand, GARRETT⁶⁾ ascertained, recently, that the corpuscles of STANNIUS arise from the walls of the pronephric ducts. He also concluded that these corpuscles are not corresponding to the adrenal cortex of mammals. His conclusion is supported by some experiments^{7), 8)}. It is apparent, therefore, from the above reasons, that the acidophile cells are the only organ corresponding to the adrenal cortex of mammals. Accordingly, in the following paper, the author calls these cells as "interrenal cells".

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Material and Methods

Ten species of teleosts used in this study are shown in Table 1. The head kidneys containing adrenal tissues were fixed in BOUIN's or ZENKER-formol fluids and imbedded in paraffin. The stains employed were MAYER's acid haemalum and eosin, GOMORI's chrome-haematoxylin and phloxine, HEIDENHAIN's iron-haematoxylin and MALLORY's trichrome stain.

Table 1. Fish species used in the study of adrenal tissues.

<i>Oncorhynchus keta</i> "Siro-sake"	<i>Girella punctata</i> "Mejina"
<i>Plecoglossus altivelis</i> "Ayu"	<i>Chrysophrys major</i> "Madai"
<i>Ctenopharyngodon idellus</i> "Sôgyo"	<i>Platycephalus indicus</i> "Kochi"
<i>Trachurus japonicus</i> "Ma-aji"	<i>Chelidonichthys kumu</i> "Hôbô"
<i>Lateolabrax japonicus</i> "Suzuki"	<i>Limanda yokohamae</i> "Mako-garei"

Microscopic observations and discussion

The head kidneys of all species of teleosts examined consist of lymphoid tissues but some uriniferous tubules are detected in the lymphoid tissues of horse mackerel, *T. japonicus*, red sea-bream, *C. major*, sea robin, *C. kumu* and of mud dab, *L. yokohamae*. In the lymphoid tissues of *C. idellus*, meanwhile, renal thyroid follicles (CHAVIN⁹⁾) are detected. In goldfish, *Carassius auratus* and carp, *Cyprinus carpio* described in the previous paper also these thyroid follicles are observed. Occasionally, in goldfish these follicles are present even in the adrenal tissues (Fig. 1-4).

Adrenal tissues, i.e. the chromaffin cells and interrenal cells are distributed in the head kidneys, surrounding the cardinal veins and their branches. The interrenal cells are found as densely packed cell groups in sweetfish, *P. altivelis* and *C. idellus* or as irregular cell-cords in the other eight species (Fig. 1-1, -2 and -5). These cells are stained with acid dyes (eosin, phloxine or acid fuchsin) and contain relatively large round or oval nucleus, in which commonly a well-defined nucleolus and a small number of chromatin are found. On the other hand, the chromaffin cells appear in the walls of the cardinal veins and their branches, or they are scattered between the interrenal cells. The chromaffin cells are stained faintly with basic dyes, and their nuclei are oval or irregular in shape and are larger than those of the interrenal cells in various kinds of fishes.

The interrenal cells have a close relationship with the chromaffin cells in their locality; six types of distribution, of both cells, were distinguished in the previous paper.¹⁾ In chum salmon, *O. keta* and *P. altivelis* the arrangements of interrenal cells and chromaffin cells belong to type III. In these fishes the chromaffin cells and the interrenal cells are distributed separately within the head kidneys and therefore both cells never come in contact (Fig. 1-2, -3, Fig. 2-1). It is of interest that the distribution of adrenal glands in these lower-grade teleosts is similar to that of adrenal glands in

lampreys¹⁰⁾, elasmobranchs¹¹⁾ or lung-fish^{12), 13)}.

In *T. japonicus*, *L. japonicus*, *C. major* and *L. yokohamae*, the chromaffin cells lie in the walls of the cardinal veins and their branches, while the groups of interrenal cells

Fig. 1. 1. Interrenal cells of *Oncorhynchus keta*. $\times 380$. 2. and 3. Head kidneys of *Plecoglossus altivelis* $\times 380$. 4. Thyroid follicle in the adrenal tissue of *Carassius auratus* $\times 380$. 5. Interrenal cells of *Nippon spinosus** $\times 370$. 6. Interrenal cells and chromaffin cells of *Paralichthys olivaceus** $\times 370$.

C, Chromaffin cells; I, Interrenal cells; L, Lymphoid tissue; T, Thyroid follicle; V, Cardinal veins.

* Adrenal tissues of these fishes are described in the previous paper²⁾.

cells surround these veins. Therefore, the arrangements of both cells in these fishes belong to type II of distribution of adrenal tissues. This type of distribution is unique in teleosts and has not been observed in the adrenal glands of other vertebrates.

Fig. 2. Semi-diagrammatic figures showing the relation of the interrenal cells to the chromaffin cells, surrounding the cardinal veins and their branches in the head kidneys.

1. *Oncorhynchus keta*; 2. *Ctenopharyngodon idellus*; 3. *Chelidonichthys kumu*; 4. *Paralichthys olivaceus*.*

I, Interrenal cells; C, Chromaffin cells; L, Lymphoid tissues of the head kidneys.

G, Ganglion cells; T, Thyroid follicle; U, Uriniferous tubules in the head kidneys; V, Cardinal veins or their branches.

* Adrenal tissue of this fish is reported in the previous paper²⁾.

In *C. idellus* as in goldfish and carp, reported in the previous paper, the interrenal cell groups lie around the cardinal veins and their branches and the chromaffin cells are scattered as separated or grouped state in these interrenal cells (Type I, Fig. 2-2). Therefore, in these tissues the interrenal cells are intermingled with the chromaffin cells and also resemble the adrenal glands of amphibians and reptiles. Adrenal tissues of characin, *Astyanax mexicanus* and killifish, *Fundulus heteroclitus* seem to belong to this type of distribution (RASQUIN⁷⁾, PICKFORD⁸⁾).

In *G. punctata*, flathead, *P. indicus* and *C. kumu* the chromaffin cells appear not only in the walls of the cardinal veins but also in the groups of the interrenal cells surrounding these veins (Fig. 2-3). This type of distribution is not described in the previous paper and the author calls it type VII of distribution.

As a conclusion, it is interesting and significant in the phylogeny of the adrenal glands of vertebrates that the interrenal cells and chromaffin cells, which are separately

distributed in lower vertebrates, are observed for the first time to be in contact in some teleosts; and that some species have adrenal glands resembling histologically those glands in various classes of vertebrates respectively, but not in mammals. In this connection, the adrenal glands of flat fish, *Paralichthys olivaceus* are similar to those of bird, as OGURI and HIBIYA reported in the previous paper²⁾ (Fig. 1-5, Fig. 2-4).

Summary

Distribution of interrenal cells and chromaffin cells in the head kidneys was investigated histologically on the adrenal glands in ten species of teleosts collected newly and also some discussion on these glands was added.

Seven species of them belong to type I, II or III of distribution described in the previous paper but *G. punctata*, *P. indicus* and *C. kumu* belong to a new type (Type VII), observed in this paper. In these fishes of type VII, chromaffin cells appear not only in the wall of the cardinal vein but also in the groups of interrenal cells surrounding the cardinal vein.

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