



Fig. 13. A sagittal section of the paraphysis (pa) and saccus dorsalis (sd) of *Arapaima gigas*.  $\times 85$ .  
 Fig. 14. A transverse section of the paraphysis (pa) of *Xenomystus nigri*. ch, cerebral hemisphere.  $\times 110$ .  
 Fig. 15. A sagittal section of the paraphysis (pa) of *Gymnarchus niloticus* (24 cm in total length). This represents a rostral component of the paraphysis and is located under the skull.  $\times 280$ .  
 Fig. 16. A sagittal section of the epithalamic circumventricular organs of *Takifugu niphobles*. dcp, diencephalic choroid plexus; h, habenula; p, pineal; pa, paraphysis.  $\times 110$ .

parapineal as clearly identified as such (for instance as seen in *Anguilla*) is not observed in these species.

**The paraphysis.** The paraphysis is found in *Arapaima*, *Notopterus*, *Xenomystus*, *Gymnarchus*,

*Leiognathus*, *Pagrus*, *Girella*, *Pseudolabrus*, *Parapercis*, and *Takifugu* (Table 1). It is absent in *Pantodon*, *Pungtungia*, *Zacco*, *Cobitis*, *Remomucenus*, *Acanthogobius*, and *Leucopsarion*.

In *Arapaima*, *Notopterus*, and *Xenomystus*, the

paraphysis is relatively large and consists of many saccules (Figs. 13, 14). Sastry and Sathyanesan (1981) also noted the occurrence of the paraphysis in *Notopterus chitala*. In *Gymnarchus*, the paraphysis consists of the rostral and caudal parts. The caudal part is represented by ependymal saccules on the membranous roof of the cerebral ventricle. The rostral part is represented by ependymal saccules extended far rostradorsally, under the rostral part of the skull (Fig. 15). In a small *Gymnarchus* (18 cm), the paraphysis is in-

distinct, but in a large *Gymnarchus* (54 cm) the paraphysis is large and consists of many saccules.

In non-osteoglossomorphs, the paraphysis is usually a small pouch which is evaginated from the ependymal roof of the cerebral ventricle. It is not conspicuously folded. In *Takifugu*, the paraphysis is a large dorsal evagination in front of the diencephalic choroid plexus (Fig. 16).

Among the species studied in the previous paper (Tsuneki, 1986), *Lepisosteus* and *Amia* (holosteans) possess a well developed paraphysis, and *Osteo-*

Table 1. The presence or absence of epithalamic ependymal structures in various teleost species<sup>1)</sup>.

	Paraphysis	Saccus dorsalis	Velum transversum	Diencephalic choroid plexus
Osteoglossomorpha				
<i>Osteoglossum bicirrhosum</i> *	+	+	+	—
<i>Arapaima gigas</i>	+	+	+	—
<i>Pantodon buchholzi</i>	—	+	+	—
<i>Notopterus chitala</i>	+	+	+	—
<i>Xenomystus nigri</i>	+	+	+	—
<i>Gnathonemus petersi</i> *	+	+	+	—
<i>Gymnarchus niloticus</i>	+	+	+	—
Elopomorpha				
<i>Anguilla japonica</i> *	+	+	+	—
Clupeomorpha				
<i>Sardinella zunasi</i> *	—	+	+	—
Euteleostei				
Salmoniformes				
<i>Hypomesus nipponensis</i> *	—	+	+	—
Cypriniformes				
<i>Pungtungia herzi</i>	—	+	+	—
<i>Zacco temmincki</i>	—	+	+	—
<i>Cobitis biwae</i>	—	+	+	—
Siluriformes				
<i>Silurus asotus</i> *	—	—	—	(+) <sup>1)</sup>
Cyprinodontiformes				
<i>Poecilia reticulata</i> *	—	—	—	(+) <sup>1)</sup>
Perciformes				
<i>Leiognathus nuchalis</i>	+	+	+	—
<i>Pagrus major</i>	+	+	+	—
<i>Girella punctata</i>	+	+	+	—
<i>Pseudolabrus japonicus</i>	+	+	+	—
<i>Parapercis sexfasciata</i>	+	+	+	—
<i>Repomucenus richardsoni</i>	—	—	—	+
<i>Odontobutis obscura</i> *	—	—	—	+
<i>Acanthogobius flavimanus</i>	—	—	—	+
<i>Leucopsarion petersi</i>	—	—	—	+
Tetraodontiformes				
<i>Takifugu niphobles</i>	+	—	—	+

<sup>1)</sup> The presence is indicated by + and the absence by —. The diencephalic choroid plexus of *Silurus* and *Poecilia* is not conspicuously folded and thus actually represents an intermediate between velum transversum and choroid plexus.

\* Species examined in a previous paper (Tsuneki, 1986).

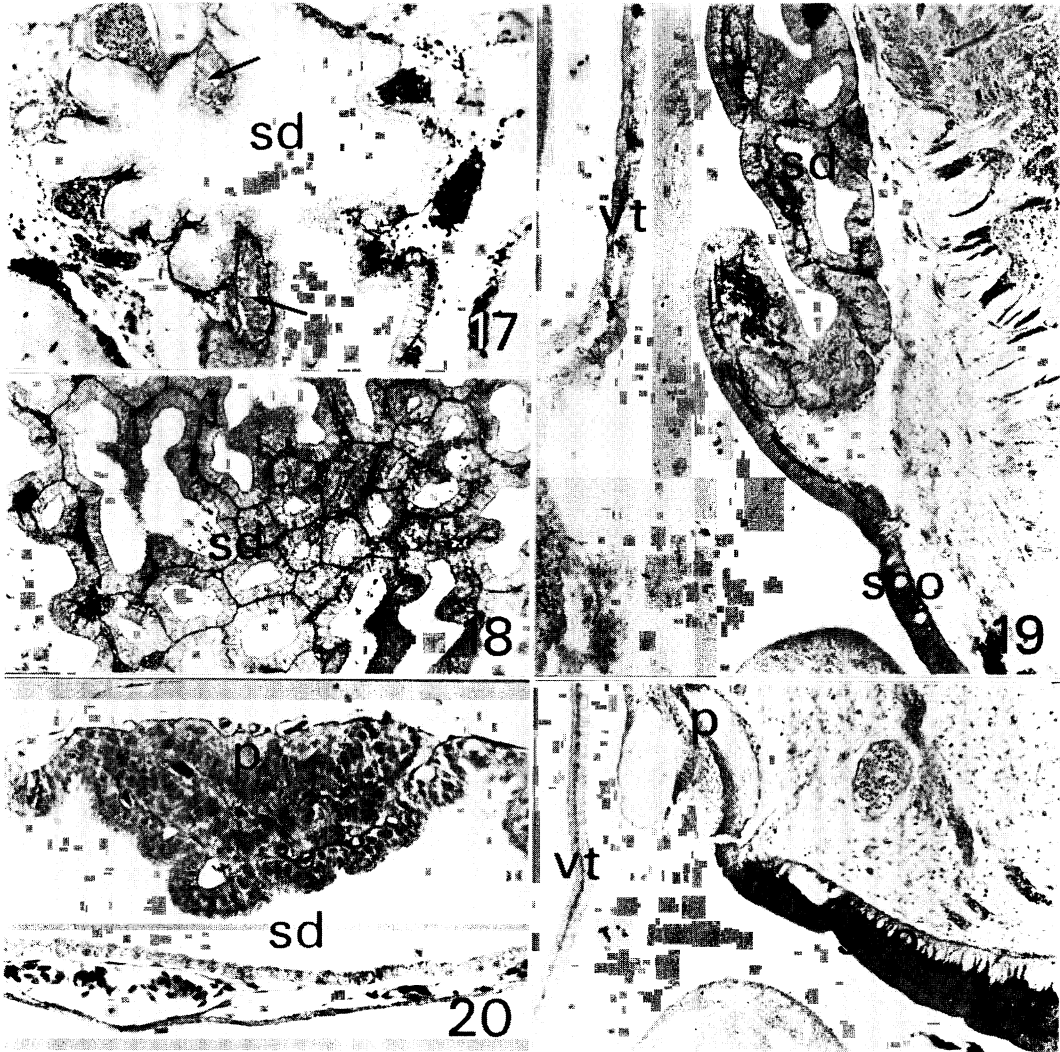


Fig. 17. A transverse section of the saccus dorsalis (sd) of *Xenomystus nigri*. Arrows indicate the pineal stalk.  $\times 110$ .

Fig. 18. A transverse section of the saccus dorsalis (sd) of *Gymnarchus niloticus*.  $\times 85$ .

Fig. 19. A sagittal section of the epithalamic circumventricular organs of *Gymnarchus niloticus*. Note the absence of the pineal. sco, subcommissural organ; sd, saccus dorsalis; vt, velum transversum.  $\times 85$ .

Fig. 20. A transverse section of the pineal (p) and saccus dorsalis (sd) of *Pantodon buchholzi*. Note capillaries between the pineal and the saccus dorsalis.  $\times 280$ .

Fig. 21. A sagittal section of the epithalamic circumventricular organs of *Arapaima gigas*. p, pineal; sco, subcommissural organ; vt, velum transversum.  $\times 85$ .

*glossum*, *Gnathonemus*, and *Anguilla* also have the paraphysis. On the contrary, *Sardinella*, *Hypomesus*, *Silurus*, *Poecilia*, and *Odontobutis* do not possess the paraphysis. Therefore, it could be suggested that the paraphysis is a primitive character of teleosts. However, the present study

showed that the paraphysis occurs in several perciform teleosts and a highly advanced teleost (*Takifugu*). Thus, trend (3) (see Introduction, the presence of the paraphysis is a primitive character state of teleosts) cannot be verified, although the large folded paraphysis consisting

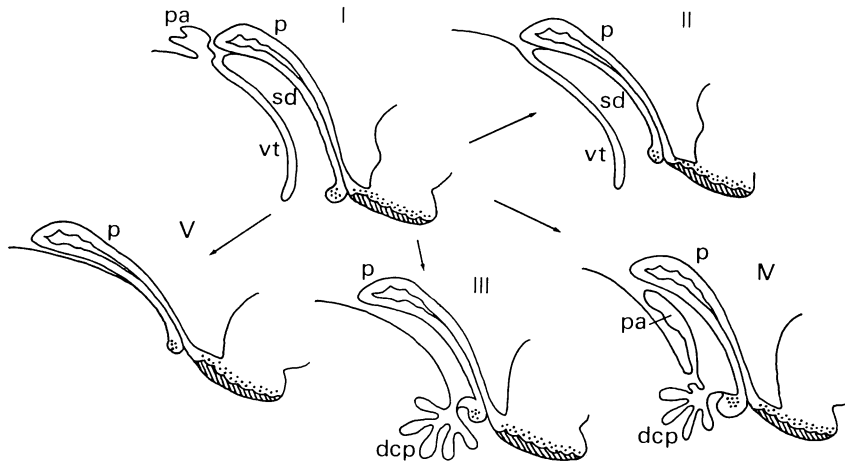


Fig. 22. Diagrammatic figures of epithalamic circumventricular organs in teleosts. The hatched area represents the subcommissural organ. The stippled area above the subcommissural organ represents the posterior commissure, and the stippled area rostral to the subcommissural organ represents the habenular commissure. Type V was figured according to the author's own preparation of the glass catfish. dcp, diencephalic choroid plexus; p, pineal; pa, paraphysis; sd, saccus dorsalis; vt, velum transversum.

of many saccules may be a primitive character.

It has been occasionally noted that teleosts do not possess the paraphysis (Leonhardt, 1980, among others), but the occurrence of the paraphysis in teleosts has been actually described in old as well as recent literature (Haller, 1922; Holmgren, 1959; Sastry and Sathyanesan, 1981; Ariëns Kappers, 1982; and others) although the description in some literature may need confirmation. There is apparently no clear-cut relation between the presence of the paraphysis and the evolutionary position or habitat of teleosts possessing the paraphysis, although teleosts belonging to a certain group (e.g. Gobiidae) may consistently lack the paraphysis.

**The saccus dorsalis, velum transversum, and diencephalic choroid plexus.** The saccus dorsalis is well developed in all species belonging to the Osteoglossomorpha and Cypriniformes studied (Figs. 13, 17–20, Table 1). The saccus dorsalis is especially well folded and sacculated in *Gymnarchus* (Figs. 18, 19). In most species, the saccus dorsalis is intimately associated with the pineal with intervening capillaries (Figs. 17, 20).

Among the investigated perciforms, the saccus dorsalis is present in *Leiognathus*, *Pagrus*, *Girella*, *Pseudolabrus*, and *Parapercis*, while it is absent in *Repomucenus*, *Acanthogobius*, and *Leucopsarion*.

*Takifugu* does not possess the saccus dorsalis (Table 1).

In all species that possess the saccus dorsalis, the velum transversum is also developed (Figs. 19, 21, Table 1). This is reasonable, because the caudal ependymal sheet of the velum transversum is actually the rostral ependymal sheet of the saccus dorsalis. In *Repomucenus*, *Acanthogobius*, *Leucopsarion*, and *Takifugu*, the velum transversum is absent but the diencephalic choroid plexus is well developed instead (Fig. 16, Table 1).

As to the ependymal organization in the epithalamus of teleosts, four or five types can be distinguished. Type I is characterized by the presence of the paraphysis, saccus dorsalis, and velum transversum. This type is found in *Arapaima*, *Notopterus*, *Xenomystus*, *Gymnarchus*, *Leiognathus*, *Pagrus*, *Girella*, *Pseudolabrus*, and *Parapercis*. Type II is characterized by the presence of the saccus dorsalis and velum transversum and by the absence of the paraphysis. This type is found in *Pantodon*, *Pungtungia*, *Zacco*, and *Cobitis*. Type III is characterized by the presence of the diencephalic choroid plexus and by the absence of the paraphysis and saccus dorsalis. This type is encountered in *Repomucenus*, *Acanthogobius*, and *Leucopsarion*. Type IV is characterized by the presence of the paraphysis and

## Tsuneki: Circumventricular Organs of Osteoglossomorpha

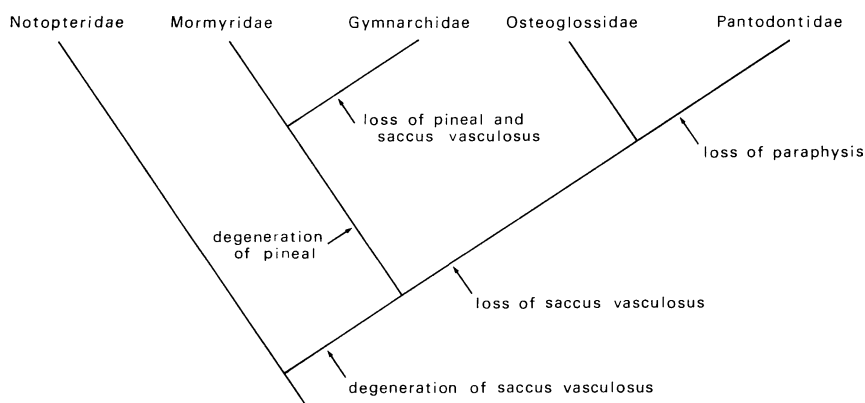


Fig. 23. Possible phylogenetic relationships of osteoglossomorphs as estimated by diencephalic circumventricular organs. This diagram represents just one of several possibilities. The Osteoglossidae, Pantodontidae, and Notopteridae are usually united as the Osteoglossiformes, and the Mormyridae and Gymnarchidae are united as the Mormyriiformes.

diencephalic choroid plexus and by the absence of the saccus dorsalis. This type is observed only in *Takifugu*. There may be one more type (type V) in which no ependymal specializations are detected in the epithalamus. Examples of this type are some silurids such as *Plotosus anguillarum* and *Arius coelatus* (Friedrich-Freksa, 1932). However, the absence of any ependymal specializations in some silurids may be secondary, because the weakly developed diencephalic choroid plexus is found in *Silurus asotus* (Tsuneki, 1986).

The functional significance of the diversity in the ependymal structures in the epithalamus of teleosts is not clear, but trend (4) itself (see Introduction; the saccus dorsalis and velum transversum are primitive characters in teleosts, while the diencephalic choroid plexus is an advanced character) may be verified. The diencephalic choroid plexus was also described in various advanced teleosts such as *Amphipnous cuchia* (Amphipnoidae), *Blennius adriaticus* (Blenniidae), *Glossogobius giurus* (Gobiidae), and *Tetraodon* sp. (Tetraodontidae) (Friedrich-Freksa, 1932; Sastry and Sathyanesan, 1981). In Fig. 22, possible evolutionary patterns of the epithalamic circumventricular organs of teleosts are diagrammatically illustrated.

**Phylogenetic relationships within the Osteoglossomorpha.** Phylogenetic relationships of osteoglossomorphs as estimated by circumventricular organs are depicted in Fig. 23. This represents just one of several possibilities. The Hiodontidae

is not included, because no information is available for circumventricular organs of hiodontids. The Mormyridae is the largest family in the Osteoglossomorpha, but the information is available only in *Gnathonemus* (Tsuneki, 1986). Circumventricular organs of many species of the Mormyridae should be investigated to make more reliable diagrams.

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### Literature cited

- Ariëns Kappers, J. 1982. The paraphysis cerebri. Pages 249–265 in E. C. Crosby and H. N. Schnitzlein, eds. Comparative correlative neuroanatomy of the vertebrate telencephalon. MacMillan, New York.
- Chiba, A. 1984. Morphological and histological studies on the endocrine glands in some Japanese plectognath fishes (Teleostei). Spec. Publ. Sado Mar. Biol. Sta., Niigata Univ., (3): 1–83. (In Japanese with English summary.)
- Dammerman, K. W. 1910. Der Saccus vasculosus der Fische ein Tiefeorgan. Z. Wiss. Zool., 96: 654–726.
- Dorn, E. 1955. Der Saccus vasculosus. Pages 140–185 in W. v. Möllendorff and W. Bargmann, eds. Handbuch der mikroskopischen Anatomie des Menschen. IV/2. Springer, Berlin.

- Friedrich-Freksa, H. 1932. Entwicklung, Bau und Bedeutung der Parietalgegend der Teleostern. Z. Wiss. Zool., 141: 52-142.
- Greenwood, P. H. 1973. Interrelationships of osteoglossomorphs. Pages 307-332 in P. H. Greenwood, R. S. Miles and C. Patterson, eds. Interrelationships of fishes. Academic Press, London.
- Haller, G. 1922. Die epithelialen Gebilde am Gehirn der Wirbeltiere. Z. Anat. Ent.-Gesch., 63: 118-202.
- Holmgren, U. 1959. On the structure of the pineal area of teleost fishes with special reference to a few deep sea fishes. Göteborgs Kungl. Vetensk. Vitterh.-Samh. Handl., Ser. B, 8: 5-66.
- Kawamoto, M. 1967. Zur Morphologie der Hypophysis cerebri von Teleostiern. Arch. Histol. Japon., 28: 123-150.
- Leonhardt, H. 1980. Ependym und circumventriculäre Organe. Pages 177-666 in A. Oksche and L. Vollrath, eds. Handbuch der mikroskopischen Anatomie des Menschen. IV/10. Springer, Berlin.
- McNulty, J. A. 1976. A comparative study of the pineal complex in the deep-sea fishes *Bathylagus wesethi* and *Nezumia liolepis*. Cell Tissue Res., 172: 205-225.
- Nelson, G. J. 1968. Gill arches of teleostean fishes of the division Osteoglossomorpha. J. Linn. Soc. (Zool.), 47: 261-277.
- Nieuwenhuys, R. 1982. An overview of the organization of the brain of actinopterygian fishes. Am. Zool., 22: 287-310.
- Omura, Y. 1975. Influence of light and darkness on the ultrastructure of the pineal organ in the blind cave fish, *Astyanax mexicanus*. Cell Tissue Res., 160: 99-112.
- Sastry, V. K. S. and A. G. Sathyanesan. 1981. A comparative study of the pineal complex of nineteen species of Indian freshwater fishes. J. Hirnforsch., 22: 327-340.
- Sathyanesan, A. G. 1972. Hypothalamo-hypophysial vascularization in a teleost fish with special reference to its tetrapodan features. Acta Anat., 81: 349-366.
- Steyn, W. and M. Webb. 1960. The pineal complex in the fish *Labeo umbratus*. Anat. Rec., 136: 79-85.
- Tsuneki, K. 1986. A survey of occurrence of about seventeen circumventricular organs in brains of various vertebrates with special reference to lower groups. J. Hirnforsch. (In press.)
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### オステオグロッサム類の間脳脳室周囲器官

常木和日子

オステオグロッサム類を中心に、各種真骨魚類の間脳脳室周囲器官を組織学的に調べた。オステオグロッサム類（ピラルク、ナイフフィッシュ、ジムナルクス）の神経性下垂体は、正中隆起と神経葉とに分化しており、全骨魚類と高等真骨魚類の中間型を示す。血管嚢はバタフライフィッシュやジムナルクスでは欠如するが、ナイフフィッシュではよく発達している。ジムナルクスには松果体も存在しない。副生体はバタフライフィッシュを除くオステオグロッサム類や、数種のスズキ目魚類に存在する。ハゼ科やフグ科等の高等真骨魚類では、背嚢や横帆を欠く代わりに、間脳脈絡叢が発達している。真骨魚類における脳室周囲器官の存否やその分化程度には、かなり系統類縁性が反映されているように思われる。

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