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Guanine Used as Retinal Tapetal Material in *Notopterus* and *Gymnarchus* (Osteoglossiformes, Notopteroidei)

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The Notopteridae, Hiodontidae, Mormyridae and Gymnarchidae are classified under one suborder, Notopteroidei (Greenwood, 1973). Mormyrid fishes are dominantly nocturnal and show a conspicuous eye shine which comes from the guanine-type retinal tapetum in the eyes (Somiya, 1989). The tapetum is an intraocular reflecting layer just behind the photoreceptor layer, and is useful for high photosensitivity in the dark. In fishes, at least six chemically different types of tapetum are found: guanine, uric acid, pteridine, lipid, astaxanthin and melanoid (Somiya, 1980, 1982; Nicol, 1981). A uric acid-type tapetum has been found only in the retina of *Hiodon* (Hiodontidae) (Zyznar et al., 1978), which belongs to the Notopteroidei. Thus, the Notopteroidei uses two kinds of chemicals as tapetal material; i. e. mormyrids use guanine and hiodontids use uric acid.

A previous paper (Somiya, 1989) presented chemical evidence showing that mormyrids use guanine as tapetal material and discussed the histological similarity of the retinal elements in the eyes of notopterid, mormyrid and gymnarchid fishes. It suggested the presence of the guanine-type retinal tapetum in the eyes of notopterid and gymnarchid species. There appears to be no literature on the chemical nature of the tapetal material in notopterids and gymnarchids. In this study, I examined tapetal material in *Notopterus* and *Gymnarchus* both spectrophotometrically and paper-chromatographically, obtaining clear evidence that such material is mainly guanine.

Materials and methods

Two specimens of *Notopterus chitala*, 70 mm and 54 mm TL (total length), and a single specimen of *Gymnarchus niloticus*, 90 mm TL, were obtained from a commercial supplier. The fish were killed by decapitation. Extraction of the reflecting substances from the retinal tapetum and the spectrophotometric and paper-chromatographic techniques employed in this study were essentially as described by Somiya (1989).

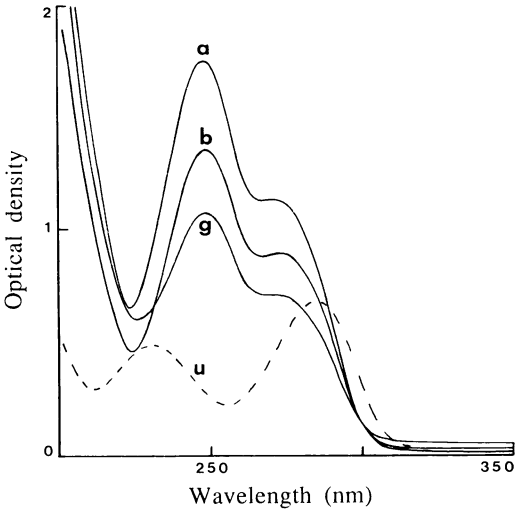

Fig. 1. Ultraviolet absorption spectra of tapetal extracts of *Notopterus chitala* (a) and *Gymnarchus niloticus* (b), authentic guanine (g) and uric acid (u) in 0.1 N HCl.

Results and discussion

The UV spectra of the tapetal extracts from *Notopterus chitala* and *Gymnarchus niloticus* were measured and compared with those of authentic guanine and uric acid in 0.1 N HCl. Fig. 1 shows that the spectra of the tapetal extracts of *N. chitala* and *G. niloticus* are the same as that of authentic guanine. Paper-chromatographically, the tapetal extracts from *N. chitala* moved at the same rate as authentic guanine in a solvent system (4 : 1 : 1 mixture on n-butanol, acetic acid and water). The Rf values for the tapetal extract, guanine and uric acid were 0.56, 0.57 and 0.34, respectively. These results clearly indicate that *N. chitala* and *G. niloticus* use mainly guanine, not uric acid, as retinal tapetal material.

Guanine content in the tapetum was estimated by the differential extinction technique (Bendich, 1957). The tapeta of *N. chitala* and *G. niloticus* contained 0.57–0.59 and 0.05 mg of guanine, respectively (Table 1). In *Notopterus*, this corresponds to a guanine distribution over approximately 2 mg cm ^{2} of the retinal surface area ($4\pi r^2/2$, r = radius of the eyeball), and in *Gymnarchus*, to approximately 1 mg cm $^{-2}$ of the retinal surface area.

The quantity of guanine measured (2 mg cm $^{-2}$) in

Notopterus was similar to that found in the tapeta of chlorophthalmid (Somiya, 1980), elopid (Ito and Nicol, 1981) and mormyrid (Somiya, 1989) fishes, but was twice as great as that of *Gymnarchus* (1 mg cm^{-2}). Both *Notopterus* and *Gymnarchus* are nocturnal. They can use their sensitive eyes only for nocturnal activity and, like mormyrids, seem to be functionally "blind" in bright daylight (Teyssedre and Moller, 1982).

Elasmobranchs and chimaerids also use guanine as tapetal material (Denton and Nicol, 1964), whereas in the Teleostei six kinds of chemicals are found as reflecting material. Histologically, these tapetal chemicals can be divided into two groups: a spherical-type reflector (lipid, astaxanthin and melanoid) and a crystalline-type reflector (guanine, uric acid and pteridine). These three crystalline-type substances have high refractive indices (1.8, 1.7 and 1.74, respectively), which are responsible for their efficient reflection (Nicol, 1981). Guanine is adopted as tapetal material in many kinds of teleosts (Osteoglossiformes, Elopiformes, Cypriniformes, Aulopiformes, Myctophiformes, Beryciformes and Perciformes) (Somiya, 1980). A reduced pteridine was found in the tapetum of two genera, *Drosoma* (Clupeiformes) and *Stizostedion* (Perciformes) (Nicol, 1981), and uric acid has been observed only in the tapetum of *Hiodon* (Zyznar et al., 1978).

The reason why *Drosoma* and *Stizostedion* use pteridine crystals as tapetal material is still obscure, but it is apparent that *Drosoma* and *Stizostedion* have developed the pteridine-type tapetum independently, in the course of their speciation. The reason why *Hiodon* uses uric acid crystals as tapetal material is also unclear. In the Notopteroidei, however, there may be some metabolic relationship between uric acid and guanine production, since they are both chemically related being based on purine.

The present study shows that the chemical properties of the retinal tapetum divide the Notopteroidei into two groups, one including the Hiodontidae and the other including the Notopteridae, Mormyridae and Gymnarchidae. The Osteoglossiformes comprise two suborders, i.e. Notopteroidei and Osteoglossoidei (Nelson, 1984). At present there is no literature on the presence of a tapetal structure in the Osteoglossoidei, although I have recently observed strong eye shine in the eyes of *Osteoglossum* (Osteoglossoidei) (unpublished data). Examination of the eyes of the Osteoglossoidei will be the subject of future research.

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Table 1. Chemical type of the retinal tapetum in Notopteroidei. A, present study; B, Somiya (1989); C, Zyznar et al. (1978).

Species (total length, mm)	Tapetum	mg/eye	mg/cm^2	Eye diameter (mm)	Reference
Notopteridae					
Notopterus chitala (70)	guanine	0.59	2.3	4.0	A
N. chitala (75)	guanine	0.57	2.3	4.0	A
Gymnarchidae					
Gymnarchus niloticus (90)	guanine	0.05	0.98	1.8	A
Mormyridae					
Marcusenius longianalis (97)	guanine	0.37	2.3	3.2	B
M. isidori (100)	guanine	0.34	1.8	3.5	B
Hiodontidae					
Hiodon alosoides (320)	uric acid	1.16	0.33	15.0	C

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Notopterus と *Gymnarchus* のグアニン型タペータム

宗宮弘明

オステオグロッサム目(ナギナタナマズ亜目)に属する *Notopterus chitala* と *Gymnarchus niloticus* は共にその眼に網膜タペータムを持つことがわかった．タペータムを構成する反射物質の主成分はグアニンであり，その量は *Notopterus* で約 2 mg/cm^2, *Gymnarchus* で約 1 mg/cm^2 であった．その結果，現在まで調べられた限りで，ナギナタナマズ亜目の魚種はすべて網膜タペータムを持つことがわかった．すなわち，これらの魚種は薄明環境にたいへん都合のよい眼球内増感装置をもつことになる．一方，タペータムの反射物質の面から，ナギナタナマズ亜目はグアニンを利用する Mormyridae, Gymnarchidae, Notopteridae と尿酸を利用する Hiodontidae の二つの群に大別された．現在のところ，タペータムの反射物質として尿酸を使う魚類は *Hiodon* 属だけである．

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