sensitivity curve for 1° 200 ms flashes on a white background may be a rather precise indicator of the functioning of the opponent-color system. Thus, although J. T. believed that his right eye was normal, the corresponding spectral sensitivity curve (continuous curve, Fig. 3) lies near the limit of the normal range, indicating that his right eye may have been partially affected by a similar defect.

There is no evidence for any response from the blue-sensitive cones of J. T.’s left eye and, in this respect, the subject’s defect may be classified as a tritan type. However, it may also be possible to interpret this finding in terms of a general loss of opponent-color function, since it is thought that the blue cones signal mainly through the opponent-color system.

The opponent-color axons in the primate retina have axons with lower conduction velocities than the luminance cells and it is thus likely that the opponent-color axons are relatively fine. For this reason, it is possible that the proposed defect of the subject’s opponent-color system may be related to selective loss or damage to small fibers or neurons.

From the Ophthalmic Optics Department, UMIST, Manchester, England. This work was supported by a grant from the Royal Society and by S.R.C. research grant B/RG/48984. Submitted for publication Oct. 8, 1975. Reprint requests: Dr. P. E. King-Smith, Ophthalmic Optics Department, UMIST, P.O. Box 88, Manchester, M60 1QD, England.

Key words: acquired color defect, opponent-color and luminance systems, cone mechanisms, spectral sensitivity, photopic luminosity.

REFERENCES


Vascularity in the reptilian spectacle. ALDEN W. MEAD.

Vascularisation of the spectacle or brille of the reptile was demonstrated by histology, histochemistry, fluorescein (in vivo), and Microfil silicone rubber (in situ) injections. This unusual vascularity provides new evidence for reassessment of the origin and development of this structure, and a useful tool with which to do so.

All snakes and those lizards without eyelids possess a permanent immovable transparent membrane totally covering the exposed anterior portion of the eye. This structure is the reptilian spectacle or brille. The study of this structure is thought to have evolved from either fusion of the eyelids or less popularly the nictitating membrane. The primary purpose of the spectacle is protection.

The study of the reptilian spectacle as an indication of the evolution of the reptilian eye and possibly the evolution of the reptile itself has been a subject of extensive discussion and investigation in the scientific literature, most especially in the field of visual science. Review of the literature by this investigator as well as a personal communication with Duke-Elder has failed to uncover evidence of previous observation of the vascularity of this structure in the English literature and mention by only one investigator in the German.

The purpose of this report is to present clearly demonstrated evidence of the vascularity of the reptilian spectacle. The study of this vascularity is suggested as a basis for re-evaluating previous information concerning the evolution of the reptilian spectacle and offer this evidence as a tool for further investigation of variations in this structure.

Materials and methods. Twenty-four reptiles, representing seven of the major families of snakes and two of the spectacle bearing lizard families were studied (Table 1). Animals were anesthetized with sodium pentobarbital 25 mg. per kilogram intraperitoneally. Biomicroscopic examination was done with a Haag Streit slit lamp on all animals. Two animals of each species were in-
Table I. Description and number of species examined

<table>
<thead>
<tr>
<th>Family</th>
<th>Species (scientific name)</th>
<th>Species (common name and number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boidae</td>
<td>Python molurus</td>
<td>Indian python (1)</td>
</tr>
<tr>
<td></td>
<td>Python reticulata</td>
<td>Reticulated python (1)</td>
</tr>
<tr>
<td></td>
<td>Boa constrictor</td>
<td>Boa constrictor (2)</td>
</tr>
<tr>
<td>Xenopelidae</td>
<td>Xenopelis unicolor</td>
<td>Sunbeam snake (1)</td>
</tr>
<tr>
<td>Acrochordidae</td>
<td>Acrochordus javanicus</td>
<td>Java wart snake (1)</td>
</tr>
<tr>
<td>Anilidae</td>
<td>Naja naja kaouthia</td>
<td>Malayan pipe snake (1)</td>
</tr>
<tr>
<td>Elapidae</td>
<td>Cylindrophis rufus</td>
<td>Siamese cobra (1)</td>
</tr>
<tr>
<td>Viperidae</td>
<td>Agkistrodon contortrix mokasen</td>
<td>Northern copperhead (1)</td>
</tr>
<tr>
<td></td>
<td>Crotalus viridis helleri</td>
<td>Pacific rattlesnake (2)</td>
</tr>
<tr>
<td></td>
<td>Bitis nasicornis</td>
<td>African rhinoceros viper (1)</td>
</tr>
<tr>
<td>Colubridae</td>
<td>Natrix sipedon sipedon</td>
<td>Northern water snake (4)</td>
</tr>
<tr>
<td></td>
<td>Thamnophis sirtalis sirtalis</td>
<td>Eastern garter snake (4)</td>
</tr>
<tr>
<td></td>
<td>Leptodeira annulata</td>
<td>Cat-eyed snake (1)</td>
</tr>
<tr>
<td>Gekonidae</td>
<td>Gecko gecko</td>
<td>Gecko lizard (2)</td>
</tr>
<tr>
<td>Xantusidae</td>
<td>Klauerina riversiana</td>
<td>Island night lizard (1)</td>
</tr>
</tbody>
</table>

*jected with microsilicone (Microfil) through the common carotid artery or its analogous structure. To allow complete perfusion of the ocular structures a suitable vein was opened for drainage. Two animals each of two species of snakes were examined by fluorescein angiography and histologically by light microscopy. Horizontal and vertical sections of whole decalcified heads were made for histological examinations.

**Results.** Microsilicone injections clearly demonstrate the vascularity of the spectacle. The microarchitectural configuration of these vessels seems to be species-dependent. There are clearly definable pattern distinctions between major families (Figs. 1 through 4). Fluorescein angiography demonstrates the same evidence and shows the vessels to fill without any obvious directional priority in the anesthetized animal.

By biomicroscopy, these vessels are seen to traverse the middle or stromal layer of the spectacle. This is interesting since this layer is not replaced during normal reptilian shedding of the skin. Visualization with the slit lamp is possible only at a power of ×32 or greater due to the small size of the vessels and the relative transparency of their walls. These vessels are then only visible due to the reflection of red blood cells circulating through them in rouleau formations. Histological examination confirmed these findings.

In at least one species of lizard (Gecko gecko; Fig. 1) there is a close anastomosing relationship between the vessels of the spectacle and some intraocular vessels.

**Discussion.** The observation of organized vascularity in the reptilian spectacle is information not previously applied to the phylogeny of the animal or the origin and development of its ocular structures. Examination and comparison of many species may establish a sequentially evolving modification of these vessels useful in the investigation of this area. There is vertical orientation of these vessels in some families of snakes and circumferential orientation in other families with degrees between them. Study and comparison of these patterns would provide valuable, additional phylogenetic information.

Preliminary investigation indicates that these vessels are also found in the spectacle of at least some fish, the toadfish being one example. A comparison between these vessels with those of the reptilian spectacle would certainly be of interest.

Perhaps the most interesting point of this work is the ability of the reptilian spectacle to maintain a vascular network and still be a tissue with a high degree of transparency comparable to the cornea or lens. This is the only example of such a phenomena as the nictitating membrane, which is also vascular, has a much lesser degree of transparency in even its most sophisticated forms. This structure would, therefore, make an interesting model for the study of compatibility between vascularity and transparency in tissue.

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**Key words:** spectacle, brille, snake, lizard, microsilicone, vascularity, transparency.
Fig. 1. Microsilicone injected eye of a lizard (Gecko gecko) of the family Gekonidae demonstrating vascularity of the spectacle. The vessels are circumferentially oriented and reticulated in pattern. (×60.)

Fig. 2. Microsilicone injection of the eye of the copperhead snake (Agkistrodon contortrix mokasen) of the family Viperidae demonstrating triangulated circumferentially oriented vessels of the spectacle. (×60.)

Fig. 3. The microsilicone injected eye of a snake of the Colubrid family, the Northern water snake (Natrix sipedon sipedon) showing quite vertically oriented vessels in a rectilinear pattern. (×150.)

Fig. 4. Specimen of a Siamese cobra (Naja naja kaouthia), an Elapid snake, demonstrating an intricate network of numerous vessels semi-vertically oriented. (×96.)
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