Ophthalmology of Scinciformata and Laterata: Skinks, Lizards, and Relatives

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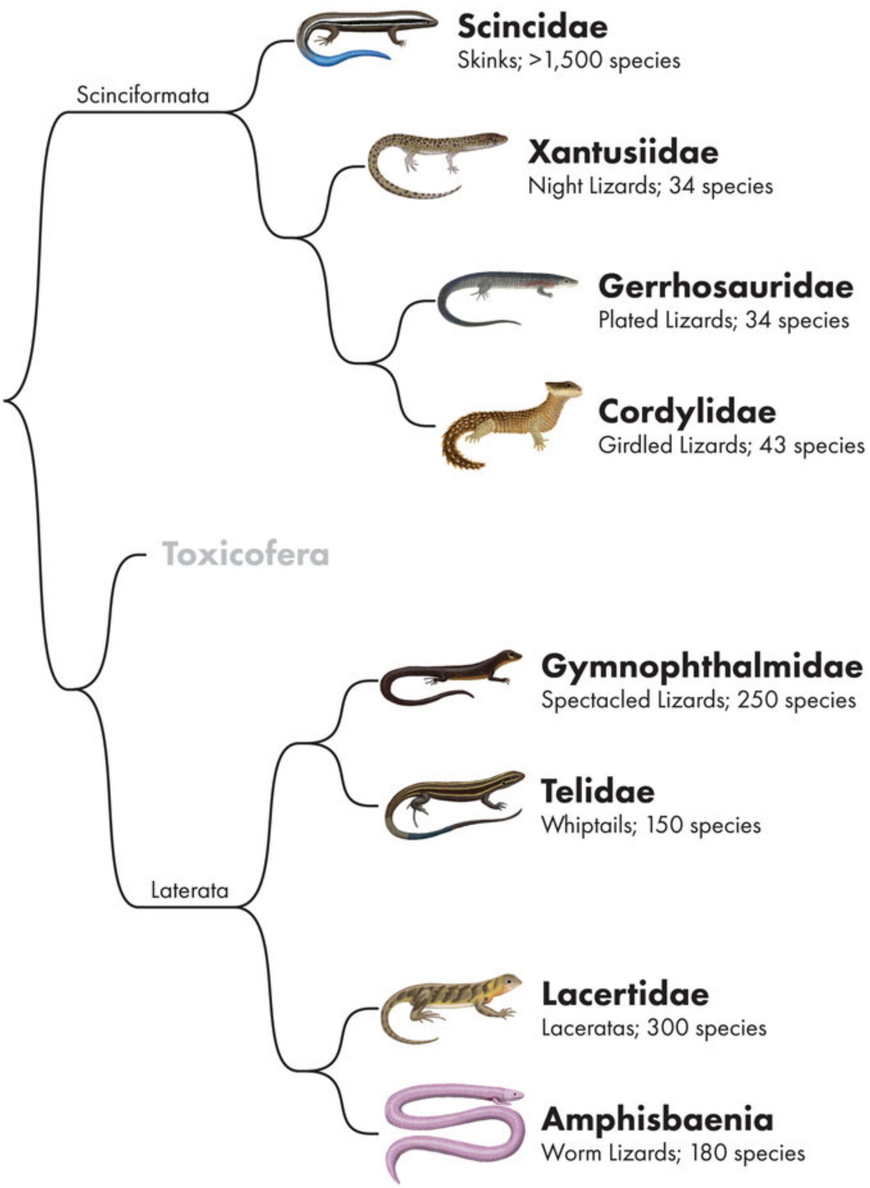
Kathryn Smith Fleming



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F. Montiani-Ferreira et al. (eds.), *Wild and Exotic Animal Ophthalmology*, https://doi.org/10.1007/978-3-030-71302-7_11

Introduction

One of the most diverse groups of terrestrial vertebrates is the reptile order Squamata, containing the lizards, snakes, and amphisbaenians (Pyron et al. 2013). Members can be found on every continent except Antarctica and some even in the ocean. Consequently, squamates also come in many shapes and sizes, possibly the most unique of which are the amphisbaenians. Phylogenetic grouping of squamates has been a recent topic of debate, largely due to the controversy between morphologic-based and molecular-based systems. New groupings meant new names as well. Scinciformata is the first branch of a group of reptiles united by the presence of one egg tooth (Vidal and Hedges 2005). It includes the skink-like lizards and families such as Scincidae and Xantusiidae. The next closely related group is the Laterata, named for the presence of tile-like scales on its members' bodies. Of the Laterata, Amphisbaenians are among the most misunderstood.

In general, limited information exists in the literature regarding the visual systems, ocular anatomy, and ophthalmic diseases that impact these lizard groups. This is in stark contrast to Iguanians (see Chap. 12). Recent studies have helped to close the gap but there remains much to be done to develop a complete ophthalmologic understanding of Laterata and Scinciformata. Their presence in captive populations such as in private homes, zoos, and research settings necessitate better understanding of the eye in health and disease (Alworth et al. 2011). With a wide range of lifestyles and habitats, lizards display a consequently wide range of visual adaptations (Walls 1942). Photopic lizards generally have a larger axial globe length relative to a smaller corneal diameter (visual acuity), while scotopic lizards have larger corneal diameter relative to a smaller axial globe length (visual sensitivity) (Hall 2008). In this chapter, ophthalmic anatomy and physiology will be discussed for each group before ophthalmic examination and disease will be considered together.

Scinciformata

As the name implies, the families included in Scinciformata contain animals that appear "skink-like." They include Scincidae (skinks), Cordylidae (girdle-tailed or spinytail lizards), Xantusiidae (night lizards), and Gerrhosauridae (plated lizards). Most skinks are surface-dwelling and diurnal, however approximately 30% are fossorial (Yovanovich et al. 2019). Skinks comprise the largest family of lizards in existence. Despite this, surprisingly little is known about their eyes. Many species of skink possess a parietal eye that is externally visible on the top of the head (Gans 1978). For a more complete discussion of the parietal eye, please see Chap. 9: Ophthalmology of Rhynchocephalia.

One of the most unique features of skink eyes is their eyelid adaptations. In some skink genera, such as *Leiolopisma* and *Trachylepsis* (formerly *Mabuya*), a portion of the lower eyelid is transparent, which enables the animal to see even when the eyelids are closed (Fig. 11.1a) (Bellairs and Boyd 1947; Millichamp et al. 1983). This unique feature goes a step further in two skink genera (*Ablepharus* and *Cryptoblepharus*) in which the eyelids are fused to form a clear spectacle (Fig. 11.1b) (O'Malley 2005). Animals with spectacles consequently lack a nictitating membrane and bursalis muscle (Underwood 1970). In-depth exploration of spectacle anatomy and physiology has been performed in snakes. It is anticipated that this information would also extend to the spectacled lizards. The reader is encouraged to review Chap. 13: Ophthalmology of Serpentes for more information.

In most species with eyelids, a Harderian gland is located ventromedially and a lacrimal gland dorsolaterally within the orbit (Baccari et al. 1990). In species with a spectacle, the lacrimal gland is typically also absent and Harderian gland secretions are released between the cornea and spectacle (Bellairs and Boyd 1947). However, the genus *Ablepharus* was found to have a lacrimal gland. The lacrimal puncta are still present but open on the posteroventral side of the spectacle (Bellairs and Boyd 1947; Underwood 1970).

A recent study on the ocular anatomy and retinal structure of the Australian sleepy lizard (*Tiliqua rugosa*), a diurnal skink, revealed several visual adaptations in this species (New et al. 2012). Individuals display a short, broad head with laterally placed eyes, creating a binocular visual field potentially 25% in width. A prominent row of scales forms a distinct brow dorsal to each eye. The Australian sleepy lizard cornea possesses 5 layers, including a thick noncellular Bowman's layer (Fig. 11.2). The anterior chamber depth is approximately 900 μm and the iris contains well-developed pupil sphincter and dilator muscles. The pupil is round and constricts in response to bright light stimulus, suggesting more prompt ability for photoreceptor adaptation to light levels. The lens is distinctly flat and composed of concentrically arranged, thin fibers surrounded by an epithelial layer, thickened at the equator as an annular pad. Zonules extend from the lens equator to the ciliary body. The anangiotic retina is 250 μm thick adjacent to the optic nerve head and lacks a fovea. The Australian sleepy lizard also possesses a prominent conus papillaris consisting of capillaries and large blood vessels interspersed with melanocytes and connective tissue (Fig. 11.3). The retina contains only single and double cones, both of which possess pale yellow oil droplets, with double cones representing 19% of all photoreceptors. Photoreceptor density peaks centrally at 76,000 cells/mm^2,

Fig. 11.1 Images of eyelid adaptations Scinciformata eyelid adaptations present in members of the Scincidae family. (**a**) A Schneider's skink (*Eumeces schneiderii*) has the lower eyelid elevated, revealing a semi-transparent area that allows continued vision while the eyelids are closed (Image from taviphoto, shutterstock.com). (**b**) In the bottom image, a juniper skink (snake-eyed skink, *Ablepharus kitaibelii*) has a clear spectacle to protect the eye instead of eyelids (Image from EdmontonMartin, shutterstock.com)

decreasing to as little as 15,900 cells/mm^2 toward the periphery. The ventral retina possesses significantly higher photoreceptor density than dorsal and there is no difference in photoreceptor density nasally vs. temporally (Fig. 11.4). Despite lacking rods, the retina of *T. rugosa* does show immunoreactivity to rhodopsin. Presence of rhodopsin in an all-cone retina could be considered an adaptation to lower the threshold of cone sensitivity, thereby increasing visual abilities in low-light settings (New et al. 2012). The lack of a fovea is consistent with the sleepy lizard's slow-moving, largely herbivorous lifestyle and consequently decreased visual demands compared to those needed for catching fast-

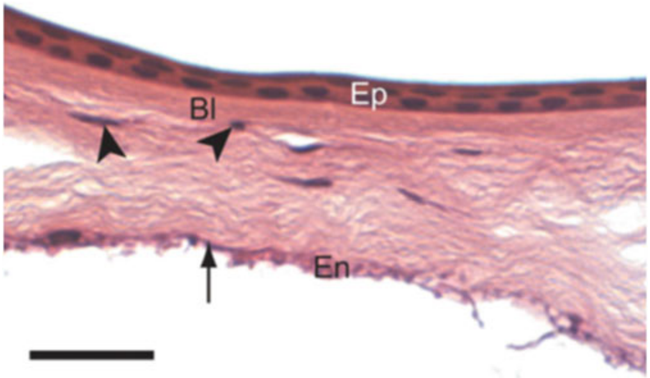


Fig. 11.2 Photomicrograph of a sectioned and H&E-stained cornea illustrating 5 corneal layers present in the Australian sleepy lizard. Keratocyte nuclei (arrowheads) are visible in the stroma. Bowman's layer (Bl), a multi-layered epithelium (Ep), Descemet's membrane (arrow), and endothelium (En) are also visible. Scale ¼ 100 μm. [*Note*: Image from New ST, Hemmi JM, Kerr GD, Bull CM (2012) Ocular anatomy and retinal photoreceptors in a skink, the sleepy lizard (*Tiliqua rugosa*). Anat Rec 295:1727–1735. Figure 3]

moving prey (New et al. 2012). In addition, the eye position in combination with uniform photoreceptor distribution across the retina creates a wide field of vision without need for directed eye movements to center objects of interest. These adaptations provide an excellent illustration of how lizard eyes have developed specializations related to lifestyle and habitat.

One study assessing the retinal structure of another diurnal skink, *Cryptoblepharus boutonii*, showed the retina to have layering typical of all vertebrates. In this species, the optic nerve is 150 μm at its intersection with the sclera and enters the globe ventronasally. *C. boutonii* possesses a conus papillaris and, unlike *T. rugosa*, also possesses a concaviclivate fovea dorsotemporal to the nerve. The parafoveal retina displays maximal thicknesses of the inner nuclear and inner plexiform layers, with the overall retinal thickness being 240 μm. The retinal thickness gradually decreases toward the periphery, ultimately reaching 80 μm. The retina is pure-cone, similar to other lizards, containing single and double cones, both with yellow or colorless oil droplets (Röll 2001). The central fovea location supports the observed monocular fixation on live prey items during feeding in this species (Röll 2001). *C. boutonii* is frequently exposed to bright sunlight yet has a spectacle, clear lens, and virtually constant pupil diameter. Therefore, it is proposed that having yellow oil droplets evenly dispersed in the retina serves a protective function to cut off short wavelength radiation from reaching deeper tissues (Röll 2001).

Visual system evolution has recently been investigated in fossorial skinks as compared to snakes (Simões et al. 2015).

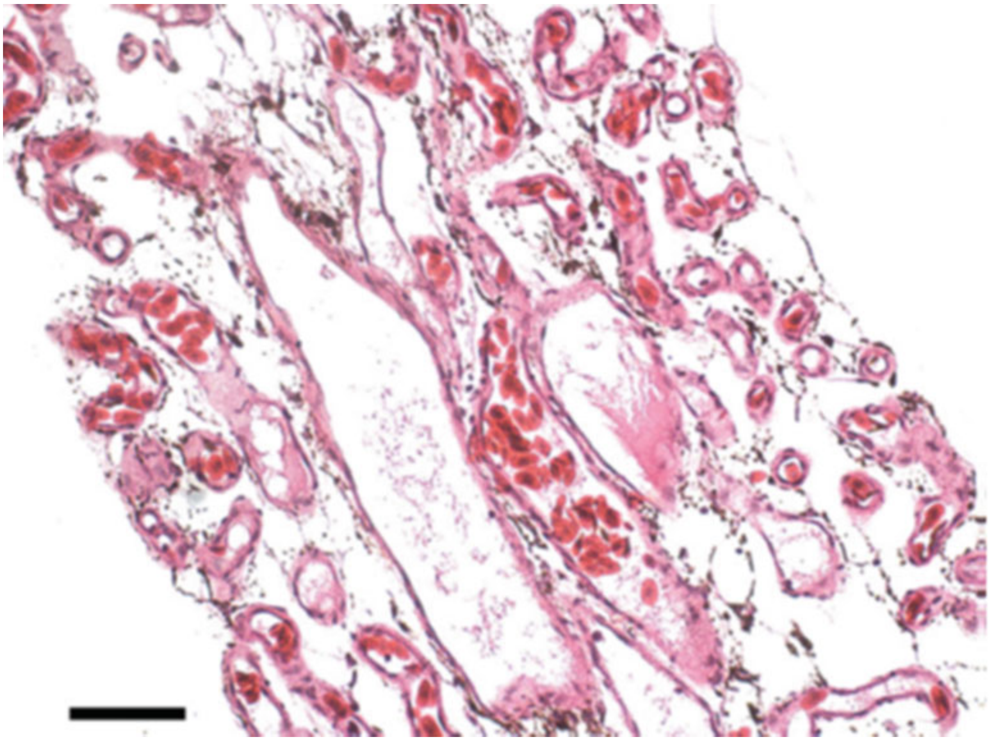


Fig. 11.3 Conus papillaris. The conus papillaris contained an extensive array of capillaries and larger blood vessels separated by a matrix of melanocytes and connective tissue. Scale ¼ 25 μm. [*Note*: Image from New ST, Hemmi JM, Kerr GD, Bull CM (2012) Ocular anatomy and retinal photoreceptors in a skink, the sleepy lizard (*Tiliqua rugosa*). Anat Rec 295:1727–1735. Figure 6]

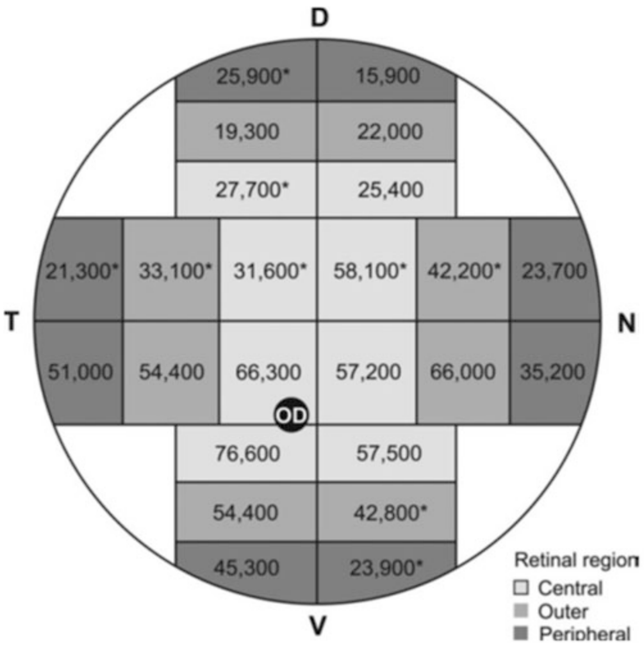


Fig. 11.4 Retinal photoreceptor density map of *Tiliqua rugosa*. Values indicate mean density (cells/mm^2) obtained from cell counts of two retinas, except those regions marked with asterisks where density was obtained from a single retina. *D* dorsal, *T* temporal, *V* ventral, *N* nasal retina, *OD* optic disc. [*Note*: Image from New ST, Hemmi JM, Kerr GD, Bull CM (2012) Ocular anatomy and retinal photoreceptors in a skink, the sleepy lizard (*Tiliqua rugosa*). Anat Rec 295:1727–1735. Figure 8]

In this study, the fossorial *Feylinia* sp. skink and Western Limbless skink (*Melanoseps occidentalis*) carried genes for 5 ancestral vertebrate opsins (rh1, rh2, sws2, sws1, and lws). In contrast, tested snakes, including fossorial species, lacked rh2 and sws2. This suggests that, even among burrowing species, visual acuity and sensitivity can vary.

Canei et al. (2020) studied the visual system of two species of sand-dwelling (psammophilic), burrowing skinks, the common sandfish (*Scincus scincus*) and the Berber skink (*Eumeces schneideri*). The sandfish lives in areas with sparse vegetation and is almost always buried in sand, whereas the Berber skink lives in areas with dense vegetation and spends more time at the surface. Both species possess a conus papillaris and lack a fovea; however, the central retina is thickest and has the highest photoreceptor density compared to other areas. Almost all photoreceptors possess a translucent oil droplet, being of larger size in peripheral photoreceptors compared to those more centrally located. Some oil droplets are colorless and likely act like miniature lenses to gather light while others are blue-green and likely serve as filters (Fig. 11.5). These species lack a tapetum. The posterior sclera is reinforced by cartilage and a ring of bony ossicles reinforces the ora serrata and ciliary body regions. The corneal epithelium and stroma of *E. schneideri* were thicker than that of *S. scincus*. “Rod-like photoreceptors,” immunoreactive for rhodopsin, are present in the central retina of both species and less so peripherally. It is unclear, however, whether these cells are truly rods or cones. Retinal ganglion cells were twice as numerous in *S. scincus* compared to *E. schneideri*. The ratio of photoreceptors to ganglion cells reveals a more linear connection in the central retina and more pyramidal pattern peripherally, suggesting these species likely possess good visual acuity. Comparing the species, *S. scincus* shows a more linear connection of photoreceptor to ganglion cell in the central retina while that of *E. schneideri* was more pyramidal. MRI was utilized to determine several ocular dimensions including axial globe length and corneal curvature (Fig. 11.6). The lens of *S. scincus* was smaller and the vitreous volume larger than that of *E. schneideri*. Results suggest these skink species have poor accommodative ability. These specializations suggest the vision of sand-dwelling skinks is adapted to bright light conditions while also possessing oil droplets to enhance vision in lower-light settings, similar to *Calyptommatus nicterus*, a fossorial Gymnophthalmid lizard (Yovanovich et al. 2019). Despite differing lifestyles, *S. scincus* and *E. schneideri* appear to have similar visual systems.

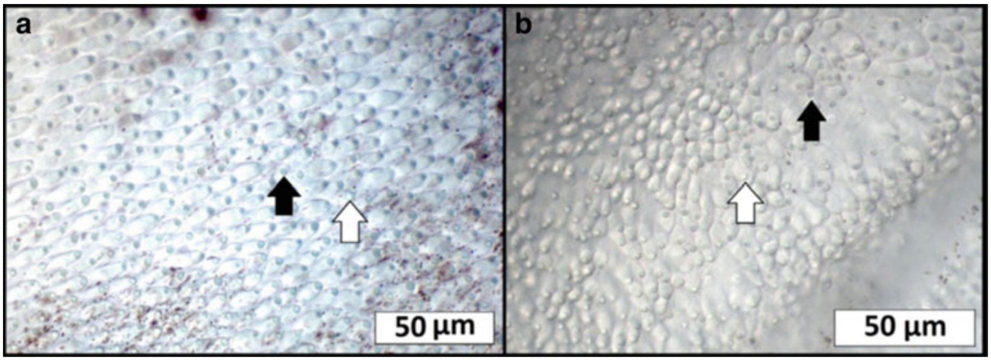


Fig. 11.5 Histologic images showing oil droplets in cones of *S. scincus* (**a**) and *E. schneideri* (**b**) The black arrows mark pale blue-green oil droplets whereas the white arrows mark colorless oil droplets associated to two distinct cone populations. [*Note*: Image from Canei J, Burtea C, Nonclercq D (2020) Comparative study of the visual system of two psammophilic lizards (*Scincus scincus* and *Eumeces schneideri*). Vision Res 171:17–30. Figure 4]

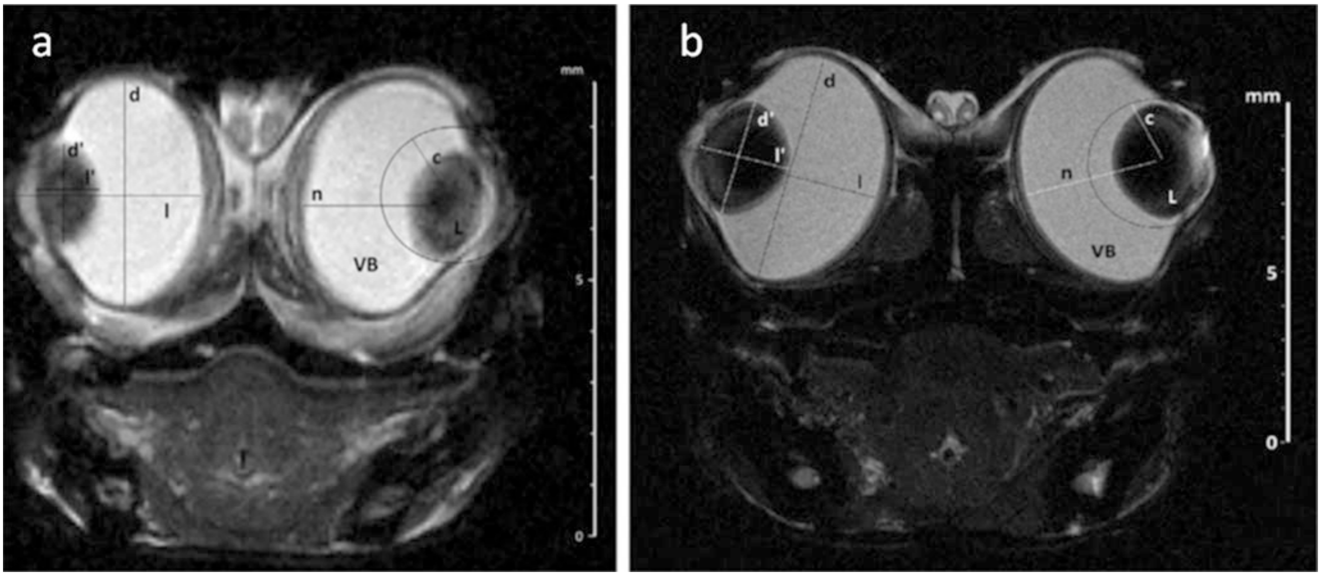


Fig. 11.6 MRI transverse plane images of *S. scincus* (**a**) and *E. schneideri* (**b**) globes. *d* ocular globe maximal diameter, *d′* lens diameter, *l* total axial length, *l′* lens length (thickness), *n* length from nodal point to central retina, *c* corneal radius of curvature, *VB* vitreous body, *L* lens. Scale on right is in millimeters. [*Note*: Image from Canei J, Burtea C, Nonclercq D (2020) Comparative study of the visual system of two psammophilic lizards (*Scincus scincus* and *Eumeces schneideri*). Vision Res 171:17–30. Figure 13]

Further visual system and retinal structure research was conducted by Zhao et al. (2020) comparing eyes of 3 fossorial skink species (*Acontias orientalis*, *Acontias rieppeli*, *Typhlosaurus vermis*) with those of a surface-dwelling skink species (*Trachylepis punctatissima*), all from southern Africa. *A. orientalis* and *A. rieppeli* are considered scotopic and have fully-developed eyes with a transparent lower eyelid (mobile in *A. orientalis* and immobile in *A. rieppeli*). However, *T. vermis* is scotopic and has highly reduced eyes. *T. punctatissima* is photopic with fully-developed eyes and mobile eyelids containing a transparent area (Zhao et al. 2020). The eyes of *T. vermis* are largely vestigial, lacking a lens and distinct retinal layers (Fig. 11.7). In this species, the outer surface of the eye contained dark brown to black granules, underneath which were many cells. Central cells stained deep purple and appeared granular whereas more peripheral cells stained light pink and contained oil droplets. The remaining 3 skink species have an ocular structure similar to other lizards (Fig. 11.7). They all lack a fovea and *A. orientalis* and *T. punctatissima* have a conus papillaris while *A. rieppeli* does not. All 3 species possess pure-cone retinas. Both *Acontias* species have a lower photoreceptor density than *T. punctatissima*. Scotopic species have a thicker photoreceptor cell layer, owing to the larger size of their cone cells, similar to what was seen in geckos (Röll 2001). Retinal layer thickness was similar between *Acontias* species but varied from that of *T. punctatissima*.

From these few studies in skinks, it is clear that visual systems vary by lifestyle in regard to light exposure, habitat, and feeding habits. Considering the species variety, much work remains to be done to better characterize ocular anatomy and physiology in Scinciformata.

Laterata

Laterata can be further divided into Lacertibaenia, containing the groups Amphisbaenia (worm lizards) and Lacertiformata ("true lizards"), and Teiformata, containing the families Teiidae (whiptails, racerunners, tegus) and Gymnophthalmidae ("spectacled" lizards). Due to variability in ophthalmic anatomy, each group will be considered separately, beginning with the worm lizards.

Amphisbaenia

Also known as worm lizards, the name Amphisbaenia is taken from the Greek "amphi" meaning double and "baen" meaning walking, referring to the ability of these animals to move forward and backward with ease (Pough et al. 2003). The origin and phylogenetic relationships of amphisbaenians have been much the topic of debate over the last century or better. Only recently using molecular analyses has there been consensus that they sit right next to Lacertids on the evolutionary tree (Vidal and Hedges 2005; Pyron et al. 2013). It is no surprise that the group Lacertiformes ("lizard-like") needed a name change to Lacertibaenia now that it included these worm-like creatures (Vidal and Hedges 2005). Amphisbaenians can be found throughout Africa, Europe,

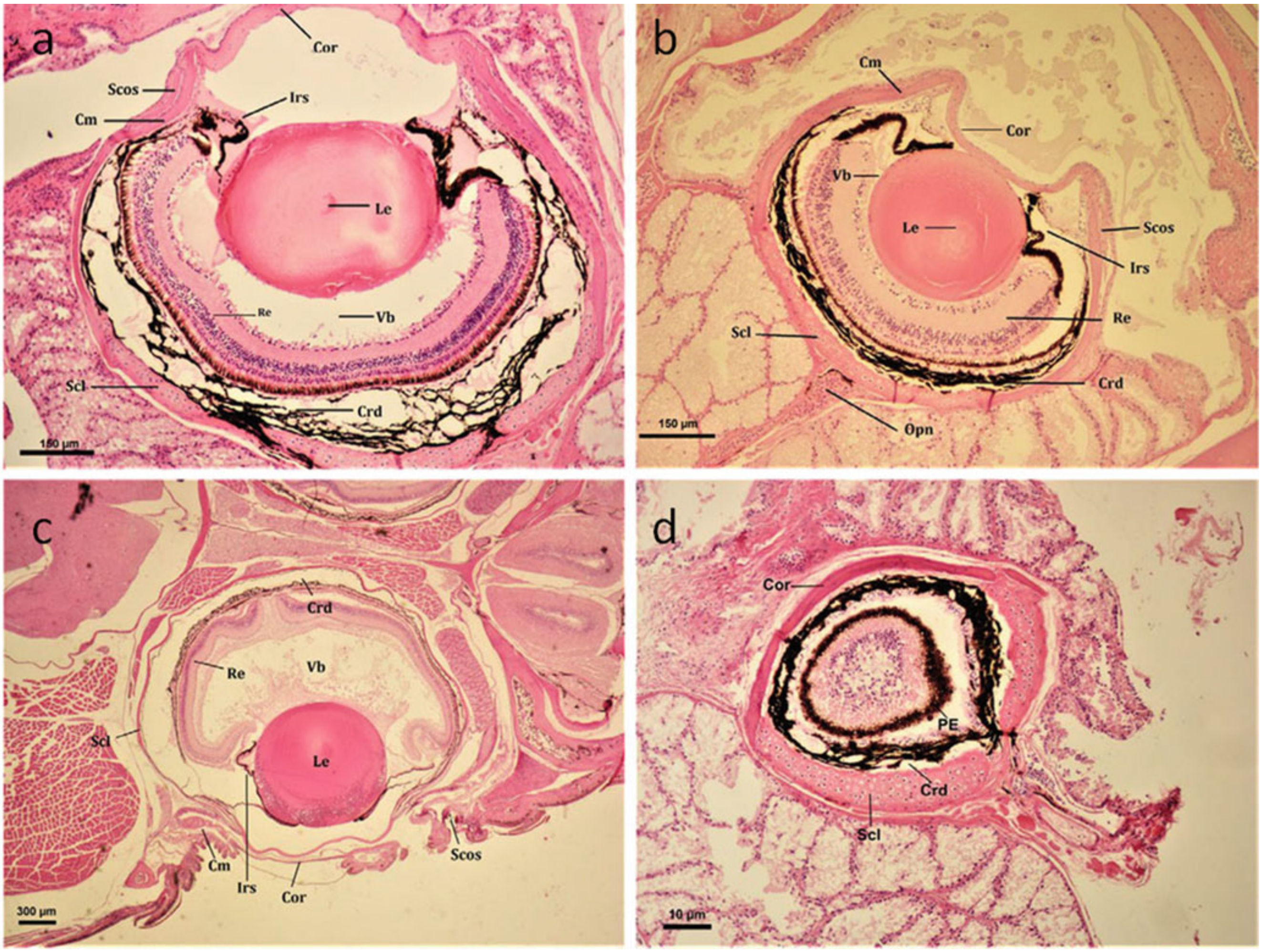


Fig. 11.7 Longitudinal histologic section of the eyes of (**a**) *A. orientalis*, (**b**) *A. rieppeli*, (**c**) *T. punctatissima*, and (**d**) *T. vermis*. *Cm* ciliary muscle, *Cor* cornea, *Crd* choroid, *Irs* iris, *Le* lens, *Opn* optic nerve, *PE* pigment epithelial layer, *Re* retina, *Scl* sclera, *Scos* scleral ossicle, *Vb* vitreous body. [*Note*: Image from Zhao Z, Goedhals J, Verdú-Ricoy J, Jordaan A, Heideman N (2020) Comparative analysis of the eye anatomy in fossorial and surface-living skink species (Reptilia: Scincidae), with special reference to the structure of the retina. Acta Zool 101:311–323. Figure 1]

and the Americas, including the Caribbean (Longrich et al. 2015).

Worm lizards are fossorial, living primarily underground. Naturally, this lifestyle has necessitated adaptations that include the ability to tunnel through sand and soil, a long body with reduced or absent limbs, and body scales arranged in circumferential rings that facilitate their unique crawling movement (Gans 1978; O'Malley 2005; Barten and Simpson 2019). Unlike their sister group, Amphisbaenians lack a parietal eye and parietal foramen but still possess a pineal gland (Taylor 1951; Gans 1978). Given the Amphisbaenians spend most of their life underground and live and hunt in near-total darkness, they are less reliant on vision than terrestrial lizards (Longrich et al. 2015). It stands to reason that an anatomic structure could change over time in response to demand or lack of use. In the case of the eye, that appears to be exactly what happened as fossorial lizards became less reliant on vision (Duke-Elder 1958; Sato 1977). Therefore, simple, underdeveloped eyes are now present in animals that live in caves or underground, like the Amphisbaenians (Fig. 11.8).

Recently, much work has been done to better understand the ocular anatomy and physiology of this unique group of reptiles. One such study outlined and compared the ocular anatomy of *Amphisbaena alba*, *Amphisbaena mertensii*, and *Leposternon infraorbitale* (Foureaux et al. 2010). Grossly, the Amphisbaenian globes are 1 mm in diameter and sit in a superolateral position in the head. The spectacle is different than that of other squamates in that it has the same external appearance as but is thinner than other scales on the head.

Fig. 11.8 Image of an Iberian worm lizard (*Blanus cinereus*) illustrating the profoundly small, underdeveloped eyes characteristic of Amphisbaenian species. (Used with permission from Jacobo Quero, Shutterstock.com)

This observation is consistent with older literature that describes amphisbaenians as having small eyes covered by a scale (Payne 1906; Walls 1942). Histologically, the spectacle epidermis has an outer keratinized layer and an inner clear zone and germinative layer (Foureaux et al. 2010). The underlying dermis is richly vascularized. Amphisbaenians have a subspectacular space (Underwood 1970; Foureaux et al. 2010) lined by epithelium, analogous to the mammalian conjunctival sac. At the edges, the epithelial lining is continuous with the corneal epithelium. In addition, a lacrimal duct extends from the anterior subspectacular space to the palatal region, similar to snakes (Bellairs and Boyd 1947).

Most amphisbaenians lack extraocular muscles and an orbital lacrimal gland but instead have a Harderian gland in the orbit that is larger than the globe itself (Bellairs and Boyd 1947; Bonin 1965). In one study, the Harderian gland was noted to fill the posterior 2/3 of the Amphisbaenian orbit (Foureaux et al. 2010). There is no interorbital septum in this group (Underwood 1970). The globe appears cup-shaped, being shorter in the anterior-posterior dimension than transversely. Some amphisbaenians lack scleral ossicles but retain cartilaginous scleral reinforcement (Atkins and Franz-Odendaal 2016). One study showed that animals with reduced or absent scleral ossicles (sclerotic ring) are always fossorial, however, the reverse is not always true as some Amphisbaenians have scleral ossicles (Atkins and Franz-Odendaal 2016). Given the sclerotic ring is thought to function in accommodation by preserving globe shape and preventing retinal distortion, its loss supports the decreased reliance on vision in these species (Walls 1942).

The cornea is adhered to the lens and iris, rendering the anterior chamber nonexistent (Fig. 11.9). In addition, the cornea has a simple epithelium and thin stromal layer but lacks a Bowman's layer, Descemet's membrane, and endothelium. The iris and ciliary body blend together and appear hypertrophied. In addition, the ciliary body lacks processes, zonules and muscles but has extensive direct lens contact. The lens is oval shaped and consists of sparsely nucleated polymorphic cells instead of fibers.

All 10 retinal layers are present. Analysis of the photoreceptor layer is consistent with the presence of lipid droplets in the outer segments. Therefore, it is believed that Amphisbaenians have a cone-rich retina. Photoreceptor outer segments are comprised of membranous discs and connect to the inner segments by cilia. These outer segments are associated with the apical processes of the retinal pigmented epithelium (Foureaux et al. 2010). Amphisbaenians lack a conus and the retina is avascular (Gans 1978).

Several hypotheses exist regarding Amphisbaenians having smaller eyes than other closely related reptiles. Since fossorial animals do not have environmental or predatory needs for agility and visual acuity, they have an evolutionary tendency for smaller globe size (Duke-Elder 1958). In addition, if the eyes are not being used as much, small globe size has the evolutionary advantage of decreasing their metabolic

Fig. 11.9 Light micrograph of cross-section of globe from *Amphisbaena alba*. Note the lack of an anterior chamber and the relatively thick retina for overall size of the globe. *C* cornea, *Cs* conjunctival sac, *Cb* ciliary body, *L* lens, *Sc* scleral cartilage, *Pe* retinal pigmented epithelium, *P* photoreceptors, *On* outer nuclear layer, *Op* outer plexiform layer, *In* inner nuclear layer, *Ip* inner plexiform layer, *Gc* ganglion cells. [*Note*: Image from Foureaux G, Egami MI, Jared C, Antoniazzi MM, Gutierre RC, Smith RL (2010) Rudimentary eyes of squamate fossorial reptiles (Amphisbaenia and Serpentes). Anat Rec 293(2): 351–357. Figure 1K]

demand for maintenance (Nikitina et al. 2004). Lastly, since Amphisbaenians dig in the soil and use their heads to advance within a tunnel, small globes are easier to protect from abrasion (Pough et al. 2003). Similar changes in the eyes are seen between Amphisbaenians and fossorial mammals including the absence of an anterior chamber and, therefore, likely also aqueous humor production (Nikitina et al. 2004).

Possessing a thinner scale over the eyes suggests an early adaption to make this area more translucent such that light could enter the underlying globe. Having nucleated cells within the lens, however, likely inhibits light transfer and retinal image formation (Foureaux et al. 2010). Therefore, the visual ability is likely limited to detection of light and variation in light intensity. Given the high metabolic rate of the retina, it would seem wasteful to maintain the layered structure without some purpose (Cernuda-Cernuda et al. 2002). In addition, Amphisbaenian photoreceptors are connected by synapses in the outer plexiform layer (Foureaux et al. 2010). Amphisbaenians have been shown to sense light and shapes (Gans and Bonin 1963). To date, electroretinography in this group has failed to show detectable response (Foureaux et al. 2010).

Regarding visual evolution, individuals of the genus *Amphisbaena* were shown to carry the genes for 5 ancestral vertebrate visual opsins including rh1, rh2, sws1, sws2, and lws (Simões et al. 2015). This is in stark contrast to all sampled snakes, which lacked rh2 and sws2, as well as dedicated burrowing snakes that only possessed rh1 (Simões et al. 2015). This difference in opsin genes despite a similar lifestyle suggests that fossoriality between snakes and amphisbaenians is not homologous. Despite a recent increase in knowledge, much remains to be learned about ocular physiology in Amphisbaenians.

Lacertiformata

Detailed studies of ocular anatomy in Lacertiform lizards are few, largely found in older literature (Underwood 1970). Almost all Lacertids are diurnal, therefore their ocular anatomy is likely similar to other lizards of similar lifestyle, such as the Iguanids (Figs. 11.10 and 11.11) (Walls 1942; Underwood 1970). Similar to skinks, some Lacertiform species have a clear area in the lower eyelid to enhance vision when the eyelids are closed (O'Malley 2005, Millichamp et al. 1983). In addition, the genus *Ophisops* has a spectacle and consequently lacks a nictitating membrane and bursalis muscle (Fig. 11.10) (Underwood 1970). In-depth exploration of spectacle anatomy and physiology has been performed in snakes. It is anticipated that this information would also extend to spectacled lizards. The reader is encouraged to review Chap. 13 (Ophthalmology of Serpentes) in this text for more information.

Many members of Lacertidae possess a parietal eye that is part of the pineal complex and externally visible on the top of the head (Gans 1978). For a more complete discussion of the

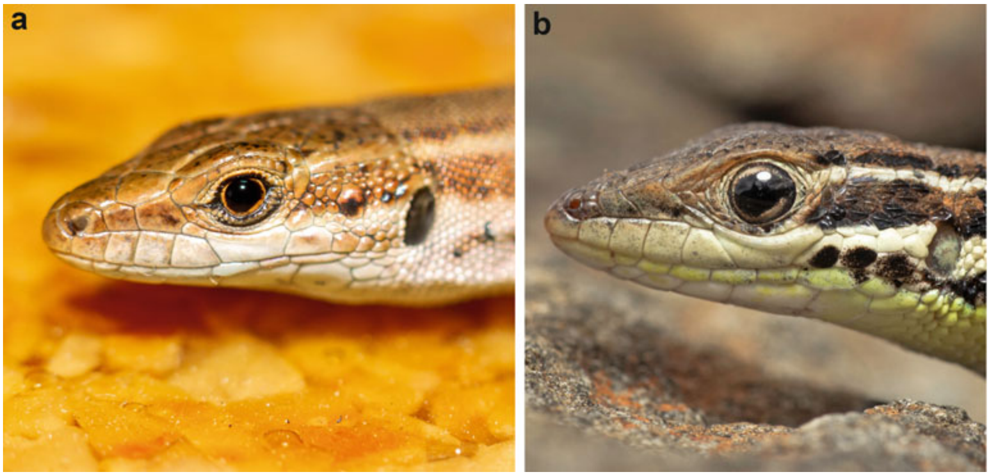


Fig. 11.10 Images of two Lacertid lizards. (**a**) Iberian wall lizard (*Podarcis hispanicus*) with typical diurnal lizard eye appearance. (**b**) Jerdon's Snake-Eyed Lizard (*Ophisops jerdonii*) with spectacle instead of eyelids. [(**a**) Used with permission from Cesar M. Amor, Shutterstock.com. (**b**) Used with permission from Sushil Kumudini Chikane, Shutterstock.com]

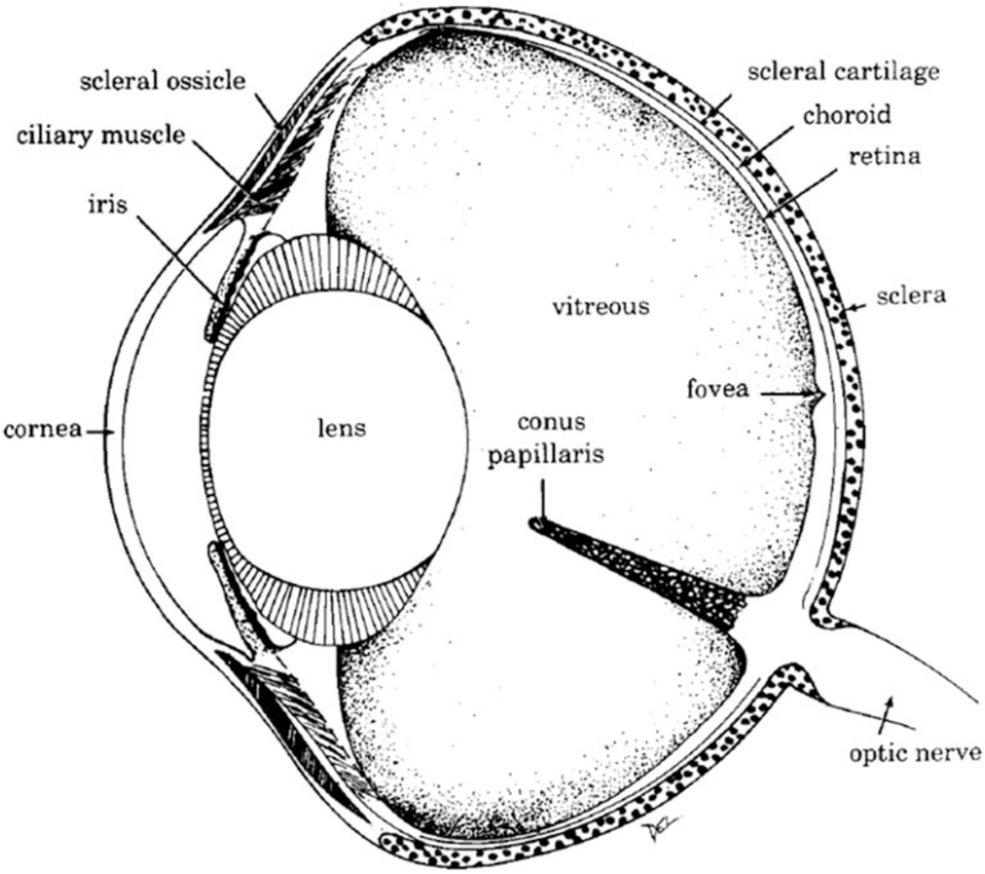


Fig. 11.11 Diagram of basic structure of Lacertid eye. [*Note*: Image from Kern TJ, Colitz CMH (2013) Exotic animal ophthalmology. In: Gelatt KN, Gilger BC, Kern TJ (eds) Veterinary ophthalmology, 5th edn. John Wiley & Sons, Ames, Iowa, p 1758–1765, p 1759, Figure 33.11. Originally adapted from Duke-Elder S (1958) System of ophthalmology, Vol I: The eye in evolution. Kimpton, London]

parietal eye, its development, and physiologic impact, the reader is encouraged to review the chapters on Ophthalmology of Rhynchocephalia (Chap. 9) and Ophthalmology of Iguania (Chap. 12) and Anguimorpha within this text.

The Lacertid globe is flattened anterior-posterior and reinforced by approximately 14 scleral ossicles anteriorly and a cartilaginous cup posteriorly (Underwood 1970). The corneal stroma is relatively thin compared to mammals, but Bowman's layer is present and quite thick. The ciliary body is broad and has extensive contact with the lens equator. Schlemm's canal can be found at the iris root. Crampton's and Brücke's muscles are present and well-developed. The lens epithelium thickens into an annular pad at the equator. Similar to birds, accommodation occurs through contraction of the ciliary muscle, annular pad compression, and resultant lens shape alteration (Underwood 1970). The pupil in most diurnal lizards is round with a small notch dorsally and ventrally. Both a conus papillaris and a fovea are likely present in most species but have not been extensively studied in this group.

In most species, a Harderian gland is located ventromedially and a lacrimal gland dorsolaterally within the orbit (Baccari et al. 1990). The anatomy of these glands was studied in a group of Italian wall lizards (*Podarcis sicula*) (Baccari et al. 1990). The Harderian gland is tongue-shaped and found adjacent to the nictitans. It has three zones, a medial mucous-secreting zone, a serous-secreting lateral zone, and an intermediate area containing secretory granules of both types. The much smaller lacrimal gland is adjacent to the lateral canthus and firmly attached to the orbital rim. It is structurally similar to the medial zone of the Harderian gland and is mucus-secreting.

It has long been known via behavioral studies that Lacertid lizards are able to distinguish colors visible in the human spectrum (Wagner 1932; Pérez i de Lanuza and Font 2014). In addition, many species have UV colorations, varying by sex and state of maturity, that could or do provide social signals (Names et al. 2019). A recent study evaluated UV vision in multiple Lacertidae clades (Pérez i de Lanuza and Font 2014). In all species and of all ocular elements examined, the lens appeared to most restrict transmittance of very short wavelength light. Retinas in all examined species possessed four oil droplet types including two apparently colorless (small and large) and two yellow (light yellow and dark yellow) types. Clear large oil droplets appear to absorb UV wavelengths whereas small clear oil droplets do not. Therefore, the small clear oil droplets are considered UV-sensitive, the large clear oil droplets short-wavelength-sensitive, the light-yellow droplets medium-wavelength-sensitive, and dark yellow droplets long-wavelength-sensitive (Pérez i de Lanuza and Font 2014). In addition, spectral tuning of the SWS1 opsin among 30 Lacertid species appears identical or very similar to that of presumed ancestral vertebrates as well as that of *Anolis carolinensis*, a species confirmed to possess UV vision. From these results, we can surmise that UV vision capabilities are common among Lacertid species. Male *Podarcis muralis* lizards were exposed to two visual stimuli differing only in their UV component and were able to discriminate between them, confirming their ability to detect near-UV light. The purpose of this ability is not clear at this time, however. Having four oil droplet types supports the notion that Lacertids have four different cones and therefore tetrachromat color vision (Pérez i de Lanuza and Font 2014). This was confirmed in a later study (Martin et al. 2015).

Reptiles have displayed remarkable response to optic nerve injury, with incredible rates of retinal ganglion cell survival as compared to similar insult in birds and mammals. That being said, although light responses may return, to date, true vision has not been recovered in these patients (Williams 2017).

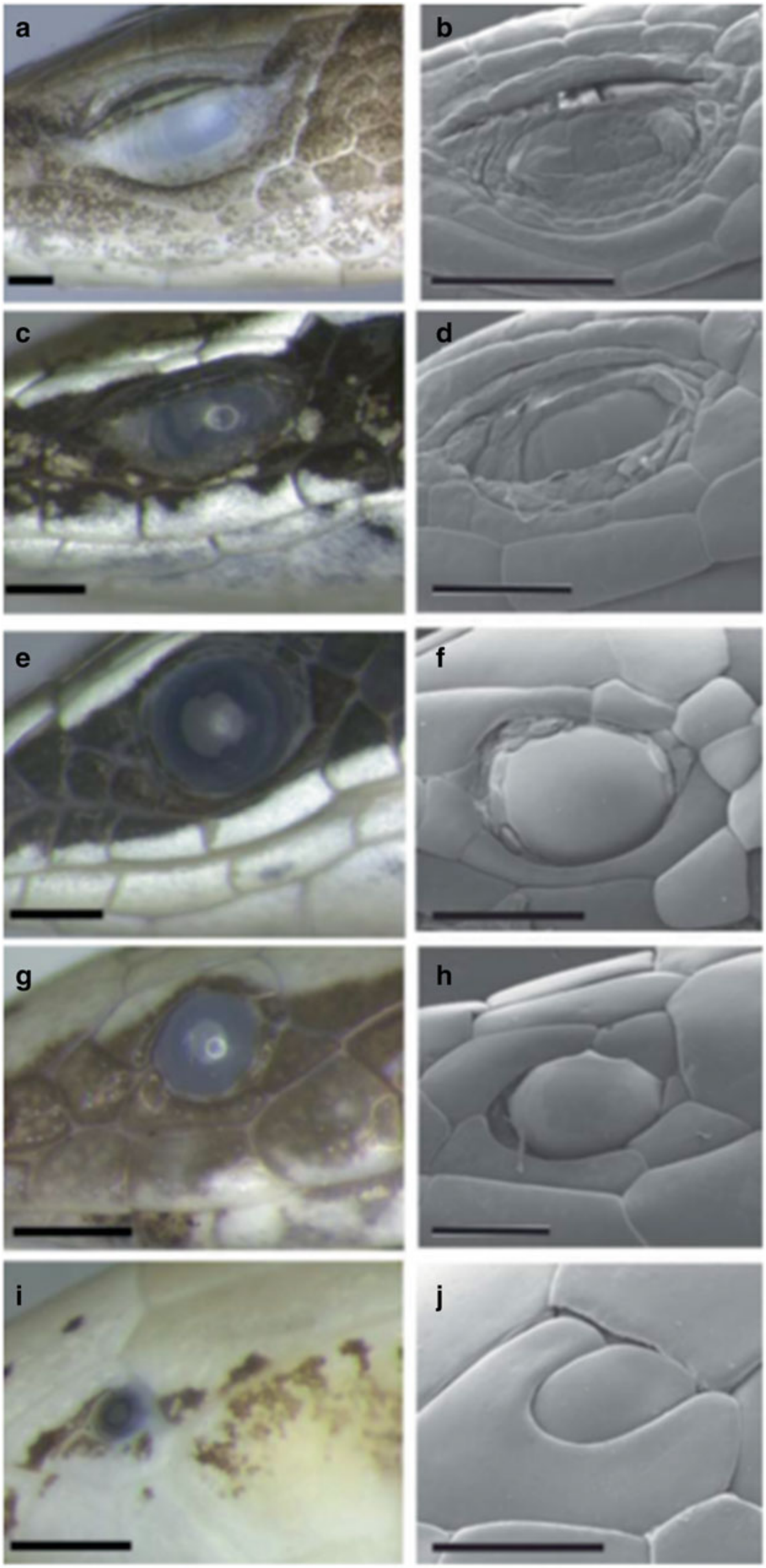
Teiformata

To date, the Teiidae family has been largely overlooked in studies of the visual system (Yovanovich et al. 2019). Some information is known, however, regarding its sister group Gymnophthalmidae. These families are largely surface-dwelling and diurnal, likely sharing similar ophthalmic structure and function to other reptiles with similar lifestyles (Underwood 1970). All known Teiids are diurnal. However, approximately 33% of Gymnophthalmids are fossorial, living primarily but not exclusively underground. Most members of Teiformata lack a parietal eye but still possess a pineal gland (Gans 1978).

The evolution of the spectacle and eyelid morphology in lizards is a topic of debate. Among the Gymnophthalmid lizards, some members have a moveable lower eyelid with a transparent scale, some have an immobile lower eyelid (always raised) with transparent scales, and some have a spectacle (Fig. 11.12) (Guerra-Fuentes et al. 2014). It is unknown, however, whether the presence of functional eyelids in Gymnophthalmids is the primitive condition or if it represents reacquisition of the trait from other eyelid morphologies (Guerra-Fuentes et al. 2014). Embryologically, in this family, it does appear that the spectacle forms from fusion of the eyelids, with the lower eyelid contributing more and the site of fusion being above the pupil region (Guerra-Fuentes et al. 2014).

Several fossorial Gymnophthalmids inhabit the sand dunes in the São Francisco River area in Brazil (Yovanovich et al. 2019). One such group are the members of genus *Calyptommatus*, all of whom possess a short tail, long body, reduced hindlimbs, and absent forelimbs, adaptations to the burrowing lifestyle. Yovanovich et al. (2019)

Fig. 11.12 Images of eyelid morphologies found in various Gymnophthalmid lizards. Left column, photographs. Right column, scanning electron micrographs of same eye pictured to left. [*Note*: Images from Guerra-Fuentes R, Roscito J, Nunes P, Oliveira-Bastos P, Antoniazzi M, Jared C, Rodrigues M (2014) Through the looking glass: the spectacle in Gymnophthalmid lizards. Anat Rec 297:496–504. Figure 3]



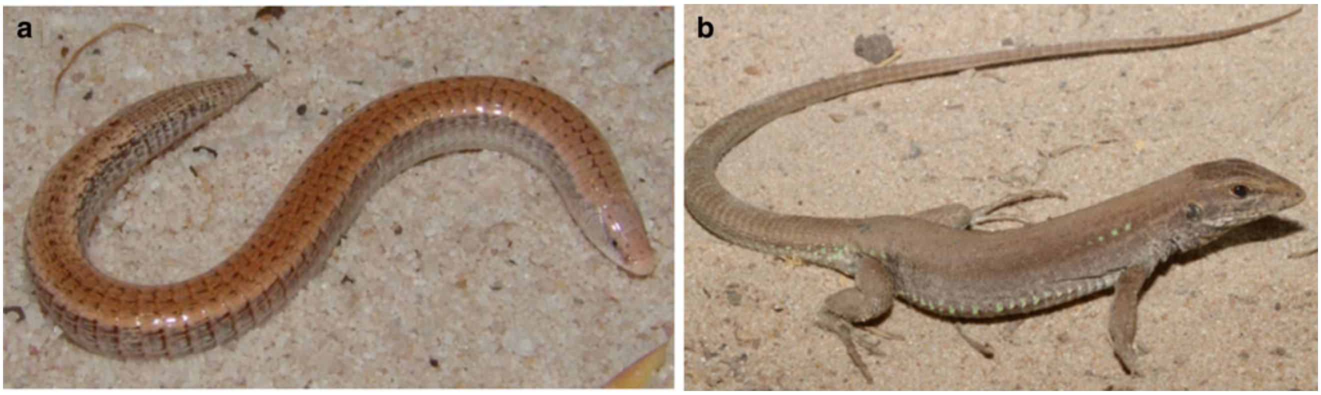


Fig. 11.13 Images of *Calyptommatus nicterus* (**a**), a fossorial Gymnophthalmid, and *Ameivula ocellifera* (**b**), a diurnal Teiid. Note the reduced eyes in *C. nicterus* and the more typical ocular appearance in *A. ocellifera*. [*Note*: Images appear in original form from Yovanovich CAM, Pierotti MER, Rodrigues MT, Grant T (2019) A dune with a view: the eyes of a neotropical fossorial lizard. Front Zool 16:17. Figure 2. Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/)]

compared the ocular anatomy and photoreceptor spectrum of *C. nicterus* with that of the Teiid *Ameivula ocellifera* to determine the extent to which the eyes were adapted from a diurnal to a fossorial lifestyle (Fig. 11.13). The globes of *C. nicterus* are spherical, approximately 600 μm in diameter, and visible as a black dot beneath a transparent scale. A ring of scleral ossicles surrounds the limbus. The iris is black and the pupil round. The lens is separated from the cornea by an anterior chamber and, unlike other lizards, lacks an annular pad. The lens is well-structured, containing concentric fibers and a layer of epithelial cells. Compared to the posterior segment size, the retina is relatively thick, leaving little room for vitreous humor. Surprisingly, the retinal structure is as expected for a vertebrate eye despite the greatly reduced ocular size (Fig. 11.14). *C. nicterus* eyes lack a conus papillaris and fovea but possess a well-developed optic nerve. The retina is cone-rich with colorless oil droplets in some single cones and the principle member of all double cones (Fig. 11.15). Overall, the cornea, lens, and spectacle of *C. nicterus* are highly transparent, allowing light photons access to the retina to maximize visual sensitivity. In contrast the eyes of diurnal *A. ocellifera* contain an annular pad around the lens and a conus papillaris but lack a fovea. The retina is similar in thickness to *C. nicterus* but proportionately thinner. The retina is cone-rich with oil droplets in single and double cones ranging from colorless to pale green-yellow to pale orange. Surprisingly, despite having very different lifestyles and eye sizes, these lizards have a very similar overall eye structure. A fovea is expected to be lacking in nocturnal lizards but not diurnal lizards, therefore its absence in *A. ocellifera* may be related to other aspects of phylogeny and/or lifestyle. *C. nicterus* lacks cones with "rod-like" outer segments that are seen in other fossorial reptiles, suggesting shallow submergence in sandy soil is a different visual environment. The authors hypothesize that typical diurnal cones may be sufficient for brief, occasional excursions above the surface in mildly lit environments (dunes more open, typically better lit than forest canopies) (Yovanovich et al. 2019). The presence of colorless oil droplets in *C. nicterus* is consistent with the need to maximize visual sensitivity in low-light settings (Walls 1942). The presence of colored oil droplets in *A. ocellifera* narrows photoreceptor spectral sensitivity. As *A. ocellifera* has 2 colors of oil droplets, this species may have well-developed color vision (Fig. 11.15) (Yovanovich et al. 2019).

Regarding visual evolution, in one recent study, the Asian grass lizard (*Takydromus sexlineatus*), a diurnal Lacertid, carried all 5 ancestral vertebrate visual opsin genes (rh1, rh2, sws1, sws2, and lws) whereas the yellow-lined Bachia (*Bachia flavescens*), a fossorial Gymnophthalmid, carried 4 opsin genes (rh1, sws1, sws2, and lws), lacking rh2 (Simões et al. 2015). That being said, the authors admit that rh2 amplification is difficult and lack of detection does not necessarily indicate true absence in the tested species. Interestingly, all tested snakes in the same study, including fossorial species, lacked genes for visual opsins rh2 and sws2. This suggests that, even among burrowing species, visual acuity and sensitivity can vary.

Ophthalmic Examination and Diagnostic Testing

Ophthalmic examination should be carried out in a systematic and logical fashion in each patient, beginning first with general observations such as overall appearance, facial symmetry, eye position, and navigating and/or feeding behaviors. Abnormalities detected can help inform and direct the remainder of the evaluation, which should proceed with examining each eye closely with a source of magnification

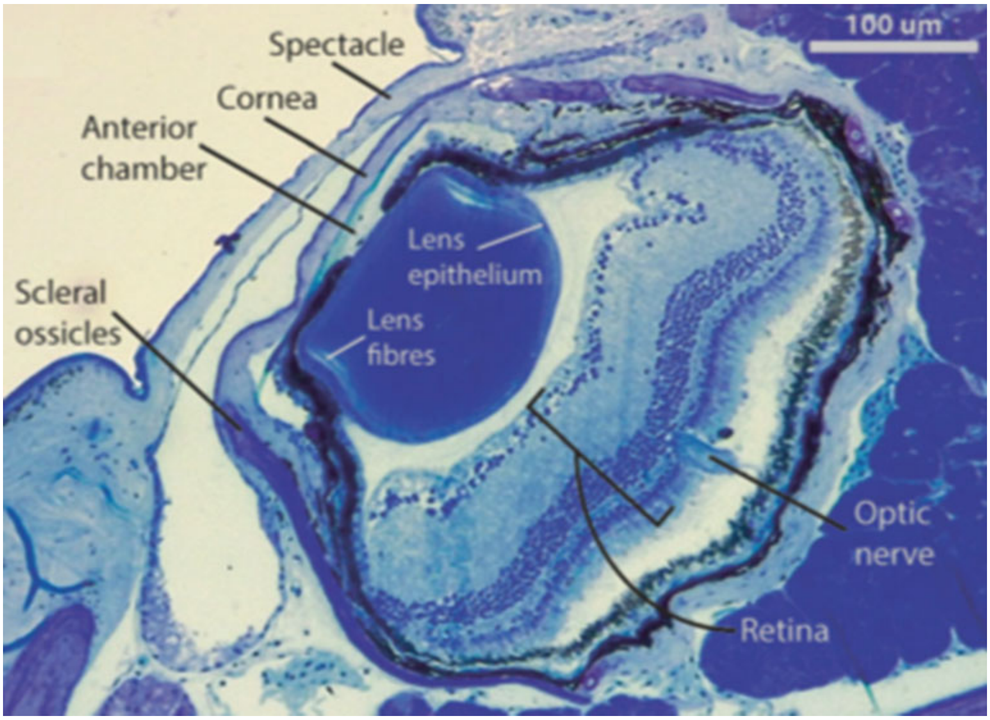


Fig. 11.14 Image of histologic section of globe from *Calyptommatus nicterus* depicting the reduced eye size and relatively thick retina with typical vertebrate layering. [*Note*: Image appears in original form from Yovanovich CAM, Pierotti MER, Rodrigues MT, Grant T (2019) A dune with a view: the eyes of a neotropical fossorial lizard. Front Zool 16:17. Figure 4A. Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/)]

(surgical loupes, magnifying glass, slit lamp, etc.) (Montiani-Ferreira 2001). When possible, it can be helpful to review pertinent literature first to gain understanding on what to expect as normal during the examination. To reduce stress, examinations should be efficient and brief. Restraint should always be performed with care and as appropriate for the species given some are easily stressed while others display caudal autotomy (O'Malley 2005; Girling 2013; Lawton 2019a). A fundic examination in these reptiles can be particularly challenging owing to small eye and pupil size. Options include panopthalmoscopy, direct ophthalmoscopy, and indirect ophthalmoscopy with a 60D or 90D condensing lens (Lawton 2019a). Direct PLR should be brisk in response to bright light and the consensual PLR absent. As reptiles typically possess skeletal muscle in the iris, tropicamide and atropine are not effective for mydriasis (Millichamp et al. 1983). Options to induce mydriasis include general anesthesia or intracameral injection of neuromuscular blocking agents (Millichamp et al. 1983; Lawton 2019a). Topical application of neuromuscular blocking agents appears ineffective in lizards and smaller reptiles, possibly relating to poor corneal penetration (Montiani-Ferreira 2001; Holmberg 2008). This explains why, in species with a spectacle, injection into the subspectacular space is also ineffective (Millichamp 1997). These medications also carry risk of systemic absorption and resultant cardiorespiratory effects. Therefore, controlled anesthesia may be a safer option (Millichamp et al. 1983).

Normal values for classic ophthalmic diagnostic tests are largely unknown in these reptile groups. Tear production tests such as Schirmer tear test and endodontic absorbent paper point tear test can be done in species lacking a spectacle. Choice of test will largely depend on palpebral fissure size. Fluorescein stain can be used to detect corneal defects in species lacking a spectacle (Lawton 2019a). It can also be used to assess patency of the nasolacrimal system (Lawton 2019a). For animals without spectacles, a drop of concentrated stain should be placed in the ventral conjunctival fornix. In animals with a spectacle, fluorescein stain can be injected very carefully into the subspectacular space using a 30 g needle placed through the lateral spectacle (Millichamp et al. 1983). This is best performed by an ophthalmologist given the potential for damaging the underlying cornea. Within a few minutes, stain should be visible flowing to the rostral end of the roof of the mouth in most species. Tonometry can be done in most species except those that

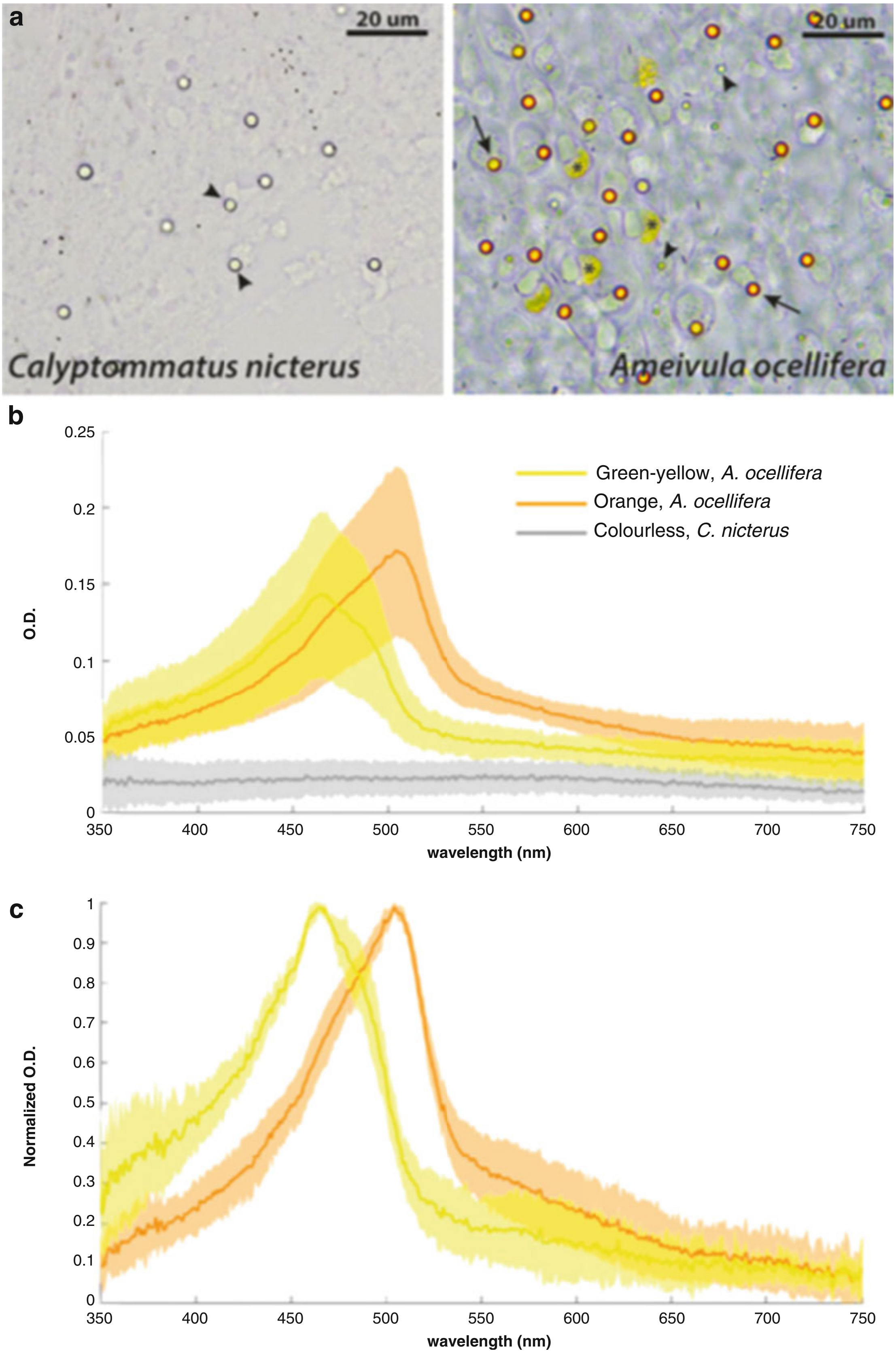


Fig. 11.15 (**a**) Images of freshly harvested retinas from *Calyptommatus nicterus* and *Ameivula ocellifera*, obtained via light microscope at 40X magnification. (**b** and **c**) Optical density (O.D.) and normalized optical density of isolated oil droplets from *C. nicterus* and *A. ocellifera* as obtained from MSP recordings. [*Note*: Images appear in original form from Yovanovich CAM, Pierotti MER, Rodrigues MT, Grant T (2019) A dune with a view: the eyes of a neotropical fossorial lizard. Front Zool 16:17. Figure 5. Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/)]

possess a spectacle. Recently, normal IOP in the black and white tegu was determined to be 9.25 ± 1.19 mmHg using the TonoPen (Montiani-Ferreira 2001).

Ocular Imaging

Radiography of the skull can be performed in routine fashion as described in the literature, including using oblique projections to reduce summation (Pees 2011). Sedation or general anesthesia is recommended when obtaining skull radiographs to provide for best positioning and reduce risk of injury (Pees 2011). References comparing gross anatomy and radiographic anatomy are available in the literature for selected species, including the tegu (Banzato et al. 2012).

Ultrasound and CT may prove particularly useful in cases of orbital disease or where direct intraocular examination is impaired, such as with eyelid swelling, opaque ocular media, or profound miosis. A 10–20 MHz linear transducer is most ideal for these studies while a 40–60 MHz transducer will provide greater detail, especially in small eyes. Transpalpebral and transcorneal (or trans-spectacle) windows can be utilized following application of topical anesthetic and a bubble-free coupling gel. As in mammals, visible structures should include the cornea, clear anterior chamber, iris and ciliary body, anterior lens capsule, posterior lens capsule, anechoic vitreous, sclera, and retrobulbar tissues. In addition, the conus papillaris should also be visible in reptiles and ranges from a small bump to a thin line extending far into the vitreous space (Hoffmann 2011). Color Doppler may be utilized to assess the conus papillaris (Araujo et al. 2017) and orbital blood flow (Mayer et al. 2010). Optical coherence tomography (OCT) has been utilized to investigate normal anterior segment morphology in select reptile species, including the blue-tongued skink (*Tiliqua scincoides*) and Western green lizard (*Lacerta bilineata*) (Rival et al. 2015). In this study, the authors demonstrated OCT can be used successfully to determine values such as anterior chamber depth and corneal thickness. However, in the normal eye, not all tissue layers are clearly discernible from surrounding tissue such as the spectacle and Bowman's layer (Rival et al. 2015).

When performing CT imaging, sedation or general anesthesia is often necessary to minimize motion artifact. Smaller lizards may be restrained in a plexiglass cage (Kiefer and Pees 2011). Use of contrast in CT of reptiles is rarely reported but can be utilized (Banzato et al. 2012, 2013). In one report, images obtained from bearded dragons (*Pogona vitticeps*) were lower quality than those of the tegu (*Tupinambis merianae*) and iguana (*Iguana iguana*), likely due to smaller size of the animal and less ability for spatial resolution (Banzato et al. 2012). Therefore, a multimodal approach to imaging may be necessary in smaller species to achieve all diagnostic goals. MRI of skink eyes has been reported and allowed measurement of various ocular dimensions (Fig. 11.6) (Canei et al. 2020).

Fig. 11.16 Conjunctivitis in a shingleback lizard (*Tiliqua rugosa*) demonstrating dried caseous debris on the eyelid margins. [*Note*: Image from Rosenwax A, Stephens T (2018) Diseases of the organs of special senses. In: Doneley B, Monks D, Johnson R, Carmel B (eds) Reptile medicine and surgery in clinical practice. John Wiley & Sons Ltd, Oxford, UK. p 357–368. Figure 26.4, p 361]

Ophthalmic Diseases

All species have been considered together in the following discussion. Some diseases have not been specifically reported in Laterata or Scinciformata species but are included due to their presence in other lizards.

Congenital Disease

Those abnormalities present at or around the time or birth or hatching are collectively defined as congenital disorders. As reptiles can be viviparous or oviparous, etiologies vary and include environmental factors such as toxin exposure or improper gestation or egg incubation temperature, as well as maternal factors and genetic abnormalities (Sabater and Pérez 2013; Lawton 2019a). Diagnosis of any congenital disease warrants evaluation of the animals bred, siblings of affected offspring, as well as the breeding and incubation processes employed (Sabater and Pérez 2013).

Of all reported congenital abnormalities, microphthalmia appears to be the most common in lizards (Millichamp et al. 1983). Microphthalmia can occur by itself or in combination with other ocular or cranial malformations (Sabater and Pérez 2013). A group of lacertid lizard (*Lacerta* spp.) hatchlings showed microphthalmia with associated reduction in size of the interorbital septum (Bellairs 1981). One study evaluating the effect of cytosine-arabinoside (Ara-C) on European green lizard (*Lacerta viridis*) eggs demonstrated cytotoxic effects resulting in growth inhibition and developmental defects including microphthalmia as well as cranial, limb, and tail deformities (Raynaud 1982). Cyclopia, or the presence of a single orbit and globe located at midline on the face, has been reported in an ocellated lizard (*Lacerta lepida*) (Bellairs 1965). True anophthalmia, defined as total congenital absence of ocular tissue, has yet to be histologically confirmed in reptiles (Millichamp et al. 1983). Therefore, alternatives such as microphthalmia, nanophthalmia, or cryptophthalmia should be considered in any reptiles appearing to lack one or both eyes (Sabater and Pérez 2013; Lawton 2019a). Histologic analysis is required to confirm anophthalmia, otherwise the condition is presumptive.

To date, colobomas have not been reported in lizards. Neither have anterior segment dysgenesis or congenital glaucoma (Sabater and Pérez 2013). Congenital exophthalmia has been reported in snakes and alligators but not yet in other types of reptiles (Cooper 1975). Often, congenital ocular malformations occur concurrently with other cranial or systemic abnormalities (Bellairs 1981; Sabater and Pérez 2013). These factors must be taken into consideration when developing treatment plans. Affected eyes should be evaluated for vision by observing feeding and other behaviors. Diagnostic testing such as electroretinography may also be possible in larger species. Any abnormality causing discomfort should be addressed and blind, painful eyes may necessitate enucleation (Sabater and Pérez 2013; Alworth et al. 2011; Lawton 2019b).

Eyelids

Traumatic injury of the eyelids may occur in any species and will typically heal with minimal intervention (Lawton 2019a). More serious injuries, however, may require surgical debridement or repair (Lawton 2019b).

Hypovitaminosis A is the most common cause of adnexal disease in reptiles but has not, to date, been specifically reported in skinks or lacertids (Millichamp et al. 1983). Low vitamin A level leads to squamous metaplasia of the Harderian and lacrimal glands, ducts, cornea, and conjunctiva as well as dry eye disease (Miller et al. 2001). Reduction in tear production leads to irritation, hyperkeratosis, loss of normal protective functions, and secondary conjunctivitis and blepharitis. Histologic examination revealed squamous metaplasia of the oronasopharyngeal mucus membranes and conjunctiva, consistent with hypovitaminosis A (Miller et al. 2001). When suspected, a thorough clinical history including diet and housing conditions should be obtained. Fluorescein stain and tear quantification (Schirmer tear test, phenol red thread, endodontic absorbent paper point test) should be performed. Treatment typically involves diet correction and vitamin A administration but should be tailored to the species and level of deficiency as over-supplementation can lead to hypervitaminosis A (Lawton 2019a). Corneal ulceration should be managed accordingly, and low tear production supplemented with topical ophthalmic lubricant. The ocular changes associated with hypovitaminosis A are often reversible, but this depends on the severity and duration of deficiency. Cases that fail to respond to therapy should be biopsied to rule out other causes of blepharitis and conjunctivitis.

Infectious blepharitis secondary to bacteria and parasites has been reported in lizards (Thomas et al. 1996). Cytology samples should be obtained and, if bacteria detected, culture and sensitivity performed. Appropriate antimicrobial therapy should be prescribed, often systemically. Abscesses and granulomas may require careful surgical drainage to provide clinical resolution while preserving eyelid function. Animals with large lesions may benefit from referral to a specialist as surgical eyelid reconstruction may be required. Granuloma and abscess contents should be analyzed by cytology as well as culture and sensitivity to direct treatment.

Virus-induced papilloma has been reported in the eyelids of green wall lizards (*Lacerta viridis*) (Millichamp et al. 1983). Diagnosis is often suspected based on clinical appearance, but biopsy and histologic examination can provide confirmation.

Conjunctiva

As in other animal groups, conjunctivitis in reptiles can arise from a multitude of etiologies including topical irritants or foreign bodies, toxins, infectious disease, hypovitaminosis A, or secondary to ocular disease. It can also occur as a consequence of capture trauma, especially in wild specimens (Wojick et al. 2013). In essence, conjunctivitis can be a primary disease or a nonspecific clinical sign (Labelle 2016). Clinical signs include conjunctival hyperemia, squinting or rubbing, chemosis (swelling), and ocular discharge. Reptiles, unlike mammals, have heterophils that lack lysosomes; therefore, mucopurulent ocular discharge is not a typical finding in bacterial conjunctivitis. Rather, conjunctival plaque formation can occur (Fig. 11.16) (Williams 2012; Rosenwax and Stephens 2018; Lawton 2019a). Patients presenting with these signs should undergo a thorough ocular and physical examination to determine the etiology. Conjunctival cytology, biopsy, and culture may be performed to determine etiology and direct treatment.

In animals with eyelids, the conjunctival fornix can be a common site for foreign body irritation, often linked with housing and substrate choices (Lawton 2019a). Bedding material can frequently cause ocular irritation, and lizards housed on peat or sand may be more likely than others to get the material in their eyes (Lawton 2019a; Holmberg 2008). Any animals with ocular irritation should be examined for conjunctival foreign body. If one is located, topical anesthetic should be applied to the eye and the offending agent manually removed under the aid of magnification. Flushing the conjunctival fornices with eye irrigation solution can also be performed, especially if a foreign body is suspected but cannot be visualized. To aid in use on the eye, the irrigation solution can be loaded into a syringe outfitted with a small (24 g) intravenous catheter. Fluorescein staining should be performed and any corneal ulceration treated with topical antibiotic.

Bacterial conjunctivitis in reptiles is rare. However, *Aeromonas liquefaciens* infection was reported in a group of laboratory-housed lizards, all from the Lacertidae family (Cooper et al. 1980). Clinical signs began as clear ocular discharge that continued for days to weeks before becoming mucopurulent and causing the eyelids to seal closed. Eyesight appeared impaired, even early on before the eyelids were sealed. Eyelid swelling developed in some animals. Most were noted to rub their eyes against objects or the ground within their enclosures. Animals eventually became listless and unable to feed with death typically occurring within 1 week of the eyelids sealing up. Necropsy confirmed conjunctivitis in all affected animals and concurrent pneumonia in several. Attempts at disinfecting the environment as well as topical and/or systemic antibiotic therapy were largely unsuccessful at controlling current or preventing new infections. A source for the infection could not be determined. Another report described bilateral conjunctivitis in a blue-tongued skink (*Tiliqua scincoides*) from which non-hemolytic *Staphylococcus* was isolated (Williams et al. 2000). Topical fusidic acid therapy resulted in clinical resolution.

Ticks can be found adjacent to the spectacle (if present) or under the conjunctiva in lizards (Millichamp et al. 1983). Treatment is by manual removal, taking care to completely remove all mouthparts so as not to encourage abscess formation. This method is safer than using agents to kill or back the tick out due to possible resultant damage to the eye.

Globe and Orbit

Exophthalmos can occur in reptiles and most often results from orbital abscess formation or periocular swelling (Hamilton et al. 1999). An orbital ultrasound can be performed to assess structures and possibly guide sampling for cytology and culture. Orbital infections can result from hematogenous spread of systemic infection, penetrating injury of orbital tissues, and foreign bodies (Hamilton et al. 1999). Treatment will depend on the underlying cause; therefore, a thorough history, physical examination, and baseline blood work are often paramount to making a definitive diagnosis. Certain infections that begin within the globe (endophthalmitis) can become severe enough to spread beyond the ocular tissues. Likewise, orbital infection can spread to involve the globe. In either case, the granulomatous response often causes globe enlargement but can also eventually result in shutdown and shrinking of the eye (*phthisis bulbi*) with time (Hamilton et al. 1999; Lawton 2019a).

Spectacle

The spectacle, when present, is shed during ecdysis. In preparation for shedding, the spectacle can often become cloudy, which, if the case, should occur at the same time the skin is turning dull. Just prior to shedding, the spectacle will clear again, confirming suspicion that this is part of the normal shedding process (Williams 2012). Spectacles can be retained, causing the eye to look lackluster and with a thin, ruffled edge to the retained tissue. Failed shed can occur due to poor husbandry and too low humidity. In other cases, it can be due to poor systemic health, previous ocular trauma, or presence of ectoparasites at the spectacle edges (Reavill and Schmidt 2012). Differential diagnoses include scarring from trauma, pseudobuphthalmos, and subspectacular abscess formation (Williams 2019). Treatment of a retained spectacle involves adjusting husbandry conditions, typically increasing humidity. Providing a damp towel in the enclosure on which the animal can rub itself may promote shedding (Williams 2012). The area can also be softened with topical application of ophthalmic lubricating gel. Manual removal of adhered tissue should be considered a last resort option as damage or complete removal of the underlying new spectacle can easily occur and could be catastrophic (Millichamp et al. 1983; Williams 2019). It may be best to leave the area alone and allow it to shed naturally in the next cycle.

Subspectacular abscess formation has been described in spectacled lizards and typically occurs unilaterally. Etiology can be from direct penetrating injury to the spectacle and inoculation of the space, ascending infection from the mouth through the nasolacrimal duct and into the space, or extension of systemic infection (Millichamp et al. 1983; Lawton 2019a). Clinical signs include a cloudy, white, or yellow appearance with or without protrusion of the spectacle. If due to extension of local disease, facial or oral swelling may also be present. Diagnosis is made based on clinical signs and analysis of subspectacular fluid. Affected animals should undergo a complete physical examination and husbandry analysis to identify an etiology. In addition, CBC and blood culture may also be warranted. Treatment is aimed at addressing the underlying etiology and cases may resolve on their own. However, therapy typically involves partial spectaculectomy with removal of a portion of the ventral spectacle and flushing of the subspectacular space (Alworth et al. 2011; Lawton 2019b). This procedure is exceedingly delicate as damage to the underlying cornea and subsequent blindness can result. If performed, the animal should be anesthetized and placed under an operating microscope for best visualization of tissue planes. Also, drained material should be collected for cytology and culture to help direct antimicrobial therapy (Millichamp et al. 1983).

Spectacle-related disease is more commonly reported in snakes and geckos. The reader is encouraged to review Chap. 13 (Ophthalmology of Serpentes) within this text regarding management of spectacular disease given diagnosis and treatment are similar and more commonly described in snakes.

Cornea

Corneal ulceration has been reported in lizards that lack a spectacle and can be associated with various factors such as foreign body, trauma, and inability to blink, similar to mammals (Lawton 2019a). Species with a spectacle are naturally more protected against corneal ulceration, but it can result from severe trauma, loss of the spectacle, and infection (Lawton 2019a). Corneal lacerations have been reported and are often traumatic. Treatment typically involves surgical repair, when possible, and topical antibiotic use (Lawton 2019a, b). Third eyelid flap placement has been reported but remains controversial due to potential for complication and limitations on monitoring (Millichamp 2002; Lawton 2019b).

Inappropriate exposure to UV lighting has been associated with corneal and dermal changes in captive reptiles (Gardiner et al. 2009). For patients with spectacles, topical antibiotic therapy will be ineffective for corneal treatment due to lack of adequate penetration. Therefore, systemic treatment or subspectacular injection may be more appropriate (Lawton 2019a).

Uvea

Uveitis and hypopyon due to *Pseudomonas* bacteremia has been reported in an Indonesian blue tongue skink (*Tiliqua gigas*). The original bacteria source was a ruptured hepatic abscess and, despite systemic gentamicin therapy, the animal succumbed to its illness (Millichamp et al. 1983). Uveitis appears to be infrequent in reptiles and may result from systemic disease, infection, neoplasia, or trauma (Millichamp et al. 1983; Labelle 2016). Hypopyon may be particularly indicative of systemic bacterial infection (Millichamp et al. 1983). Topical and/or systemic NSAID therapy should be instituted and corticosteroid therapy avoided without absolute necessity (Lawton 2019a). Topical atropine therapy is ineffective due to the presence of striated musculature, as in birds (Holmberg 2008).

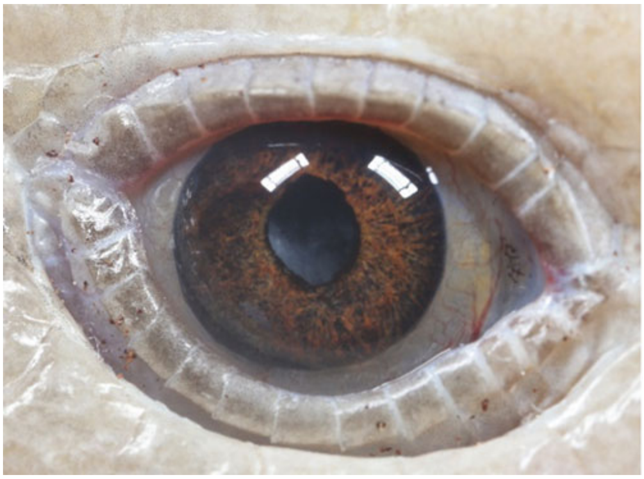


Fig. 11.17 Image of blue-tongued skink *Tiliqua* sp. diagnosed with a hypermature cataract. (Courtesy of Bret A. Moore)

Lens

Cataracts have been documented in many reptile species, including skinks, and occur for a variety of reasons (Fig. 11.17). Age, environment, and nutrition remain the most highly suspected causes in captive animals, similar to other reptile species. Cataract surgery has been performed in several species of monitor lizards but has not been documented in any members of Laterata or Scinciformata.

Glaucoma

Glaucoma has not been reported in lizard species to date, perhaps owing to lack of knowledge of normal intraocular pressure ranges in most species. Recently, normal IOP in the black and white tegu (*Tupinambis merianae*) was measured at 9.25 ± 1.19 mmHg using the TonoPen (see Appendix A) (Montiani-Ferreira 2001).

Retina

In comparison to other veterinary species groups, very little is known about retinal disease in reptiles. This could be in part due to the challenge of performing a fundic examination in these species or that patients do not present for evaluation until complete blindness has occurred (Millichamp 2002).

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