Ophthalmology of Mustelidae: Otters, Ferrets, Skunks, Raccoons, and Relatives

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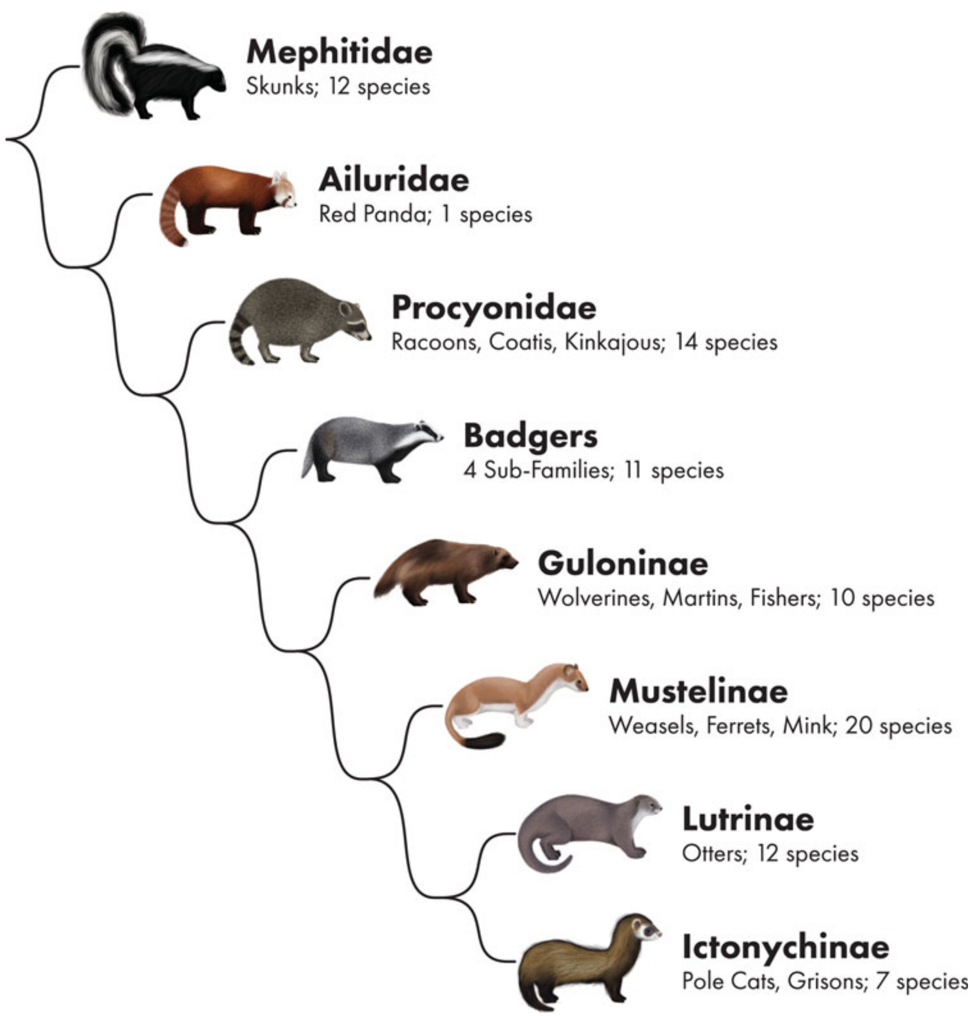

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Introduction

The Musteloidea superfamily of carnivoran mammals consists of the families Ailuridae (red pandas), Mustelidae (mustelids: weasels, otters, martens, and badgers), Procyonidae (procyonids: raccoons, coatis, kinkajous, olingos, olinguitos, ringtails, and cacomistles), and

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Mephitidae (skunks and stink badgers). The Mustelidae family, whose members are collectively known as mustelids, includes terrestrial forms (such as ferrets and skunks), arboreal species (such as martens), burrowing species (such as badgers), semiaquatic species (such as minks), and aquatic species (such as otters) (Burnie and Wilson 2001). The main physical links between all mustelids are shared characters of the skull and teeth, usually short legs and elongated bodies (Fujishiro et al. 2014).

Ferrets

Of all the species in the mustelidae family, the domestic ferret is certainly the species of greatest veterinary importance, since domestic ferrets are becoming more popular as pets and are increasingly been seen as a patient in different veterinary services. The complete scientific name for the domestic ferret is *Mustela putorius furo*. *Mustela* is a hybrid word meaning "long mouse," and is a combination of *mus*, which means mouse in Latin, and *theon* [*telos*], which means long in Greek. The term was originally used to refer to the weasel. The word *putorius* comes from the Latin, meaning "stench," referring to the musky odor of the ferret. The word *furo* also comes from the Latin *fur* meaning thief, and *furittus* meaning little thief. Therefore, a loose translation for the scientific name of the ferret would be "stinky weasel thief" and for the English name, ferret, would be just "little thief." It is believed that ferrets were domesticated approximately 2000 years ago, primarily for hunting purposes, becoming more popular worldwide as pets in the 1980s (Burnie and Wilson 2001; Huynh et al. 2017).

Ferrets also are commonly used as animal models for medical research initially for influenza and later for other diseases, including several ophthalmic investigations, such as particularly glaucoma, retinal morphology, and central vision pathways (Liets et al. 2003; Hoffmann et al. 2004; Aboelela and Robinson 2004; Manger et al. 2004; Chen et al. 2005; Hoar 1984; Fujishiro et al. 2014). Knowledge of normal parameters for the main ocular tests, fundamentals of ocular examination, basic anatomical features and the most common ocular diseases of the domestic ferret became a necessity for practicing veterinary ophthalmologists. Normal ocular values for selected ophthalmic tests and ocular biometry have been documented (Gaarder and Kern 2001; Montiani-Ferreira et al. 2006; Hernández-Guerra et al. 2007). Case reports of ferrets presenting different ocular conditions also have been published (Miller and Pickett 1989; Miller et al. 1993; Lipsitz et al. 2001; McBride et al. 2009; Ropstad et al. 2011; DiGirolamo et al. 2013; Verboven et al. 2014; Lindemann et al. 2016). Literature reviews concerning ferret vision, ocular examination, anatomical features of the eye as well as general ophthalmology are available (Miller 1997; Good 2002; van der Woerdt 2003; Gaarder and Kern 2001; Montiani-Ferreira 2009; Myrna and Girolamo 2019).

Basic Anatomical Features of the Ferret Eye

One important anatomical aspect of the ferret eye concerns the globe size, which is proportionally and absolutely small (approximately 7 mm of axial length) (Hernández-Guerra et al. 2007; Fujishiro et al. 2014). Ferrets possess a relatively large lens (about 3.5 mm) and a wide cornea for optimal light gathering in dim light conditions (Williams 2012). However, ferrets eyeballs are absolutely larger than those of rodents (Fujishiro et al. 2014). The globes are placed somewhat laterally in the skull (32° from the midline) giving a field of view of around 270°, but with a very limited binocular vision (approximately 40° frontally) (Fig. 39.1a) (Good 2002; Garipis et al. 2003; Williams 2012).

Ferret newborns are called kits and similarly to puppies are born with closed eyelids. Canine eyelids open at approximately 2 weeks after birth in most breeds (Montiani-Ferreira et al. 2003), whereas the eyelids of ferrets do not open until after 20 days after birth (Miller 1997; Gaarder and Kern 2001; Good 2002; Williams and Gum 2013).

Similar to other carnivores, ferrets have a well-developed third eyelid (semilunar fold of the conjunctiva) that is reinforced by a T-shaped cartilage. A lacrimal gland is present and is responsible for secreting a significant portion of the aqueous layer of the tear film. A firmly adherent conjunctiva is present on both the bulbar and the palpebral surfaces of the third eyelid. The ferret's third eyelid can be non-pigmented (whitish) or pigmented at the margin. There is no deep gland (Harderian gland) of the third eyelid in the ferret. Exposure of the palpebral (external) surface of the third eyelid can be obtained by manually retracting the globe back into the orbit (gentle digital retropulsion).

As in most species adapted for night vision, the corneal surface of the ferret is large, compared to dogs and cats. As in most species adapted for night vision, the corneal surface of the ferret is large, compared to dogs and cats. The mean central corneal thickness in the adult ferret is about 0.34 mm (Montiani-Ferreira et al. 2006). The corneal epithelium is nonkeratinized stratified squamous and approximately 4–5 cell layers thick, and is avascular (Montiani-Ferreira 2009). The other corneal layers are comparable to that of other carnivores but total about half the thickness of an adult dog cornea (Montiani-Ferreira et al. 2003, 2006).

The iris of ferrets are thin and most commonly heavily pigmented (Fig. 39.1a) with the exception of albino ferrets in which the iris is usually red-pink in color (Montiani-Ferreira 2009). The pupil is round when mydriatic but is peculiarly horizontally ovoid when miotic (Fig. 39.1b).

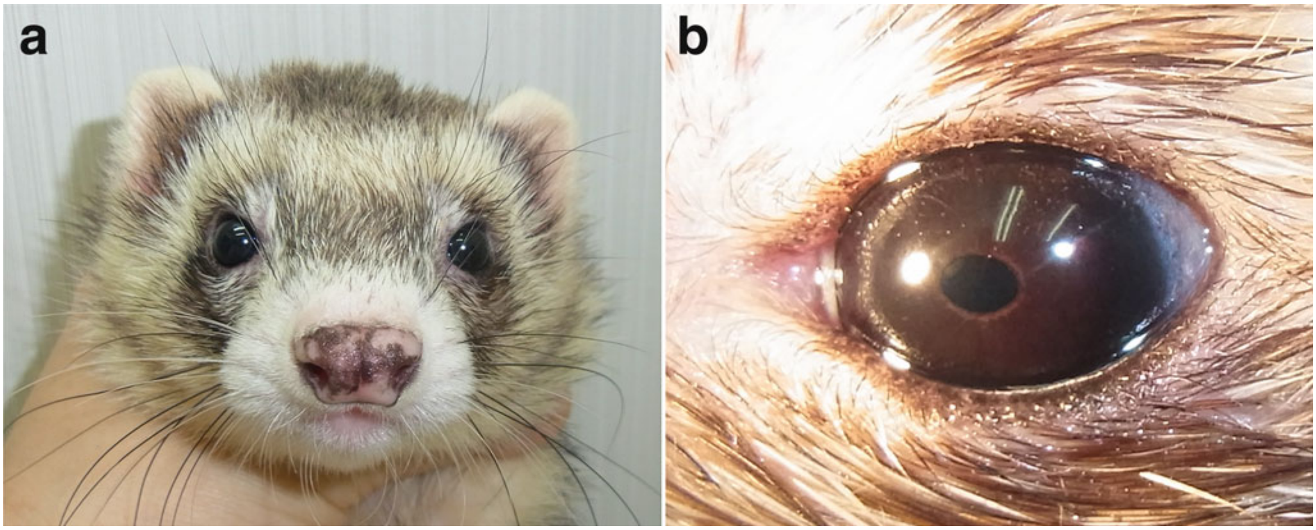

Fig. 39.1 (**a**) Note that the eyes of the ferret are positioned slightly laterally in the skull providing a limited binocular vision. (**b**) Note that the pupil of this *brown*-eyed ferret is oval, horizontally oriented, when in miosis. (Courtesy of Yasutsugu Miwa)

Phylogenetically close wild mustelids possess crepuscular habits, hunting typically at dusk and dawn (Williams 2012). Consequently, evolutionary speaking the ferret eye has a predominantly rod-dominated retina, specialized for function in dim light. The threshold of light needed for vision in the ferret is estimated to be five to seven times lower than in humans (Williams and Gum 2013). Darkly pigmented ferrets possess a brightly reflective choroidal and cellular tapetum lucidum of variable size and color. The color of the tapetal area seems to be influenced by coat color and age, with tapetal colors ranging from bluish (in young individuals) to yellow-green to dark orange (in brown, gray, black-coated individuals) (Fig. 39.2a, c). Albino and subalbinotic ferrets may lack partially or totally a tapetum, and when present they tend to be more of a light orange color. However, histologically, lightly colored individuals were reported to have a tapetum lucidum similar to that of the pigmented wild-type ferret (Tjalve and Frank 1984) (Fig. 39.2b, d). The ferret tapetum is rich in zinc and cysteine (Tjalve and Frank 1984; Braekevelt 1981). The retina is vascular in a holangiotic pattern with a small and poorly myelinated optic disc (Gaarder and Kern 2001) (Fig. 39.2c, d). In pigmented ferrets, 6000 retinal ganglion cells project ipsilaterally from the temporal area to the brain, whereas in albino ferrets only 1500 do so (Morgan et al. 1987). The impact of this difference has yet to be investigated. Overall, the axon count and density of optic nerve of the pigmented ferret is 82,000–88,000 (Henderson 1985). The Ferret retina possesses a prominent horizontal streak with the highest cellular density at the area centralis (Henderson 1985; Williams 2012), which is an area of increased photoreceptor and ganglion cell density, located superiorly and temporally to the optic disc. In terms of Snellen acuity, the pigmented ferret's visual resolution is 20/170 in bright light and 20/350 in dim light (Williams 2012). Ferrets are dichromats, thus possess two different cone populations within the retina, with a peak cone density of about 26,000/mm^2 with a peak rod density of 350,000/mm^2. They can detect moving objects (at the speed of a running mouse) better rather than stationary ones, and objects moving at 25–45 cm/s are optimally visualized (Hupfeld et al. 2006).

Knowledge of the ferret skull's intricate gross and radiographic anatomy is crucial for radiographic positioning, interpretation, as well as planning for safe surgical approaches. Descriptive and illustrated radiographic anatomy of the ferret is available elsewhere (Silverman and Tell 2005). The bony orbit of the ferret is deep and incomplete (open) (Fig. 39.3). As a result, it can be challenging for owners or keepers to detect a space-occupying lesion until it has reached a significant size (He and Killiaridis 2004). Ferrets possess a noticeable frontal process of the zygomatic bone and a salient lacrimal process, close to the maxilolacrimal suture line. The bony orbital margin has an outline that resembles an incomplete circle interrupted only by the prominent lacrimal process rostrally**.** The domestic ferret has an oval-shaped infraorbital foramen. At the orbital aspect of the lacrimal bone lies the fossa (or pit) of the lacrimal sac ventral to the lacrimal process. Only two foramina are present caudally at the medial wall of the orbit, the optic canal and, caudoventrally to this one, the orbitorotundum foramen. The orbitorotundum foramen is considered to be the result of the fusion of the orbital fissure and round foramen, and it is not present in other species of carnivores. One or two ethmoidal foramina may be present. As in dogs, a maxillary foramen is found at the orbital aspect of the maxillary bone, and two other foramina, the sphenopalatine and caudal

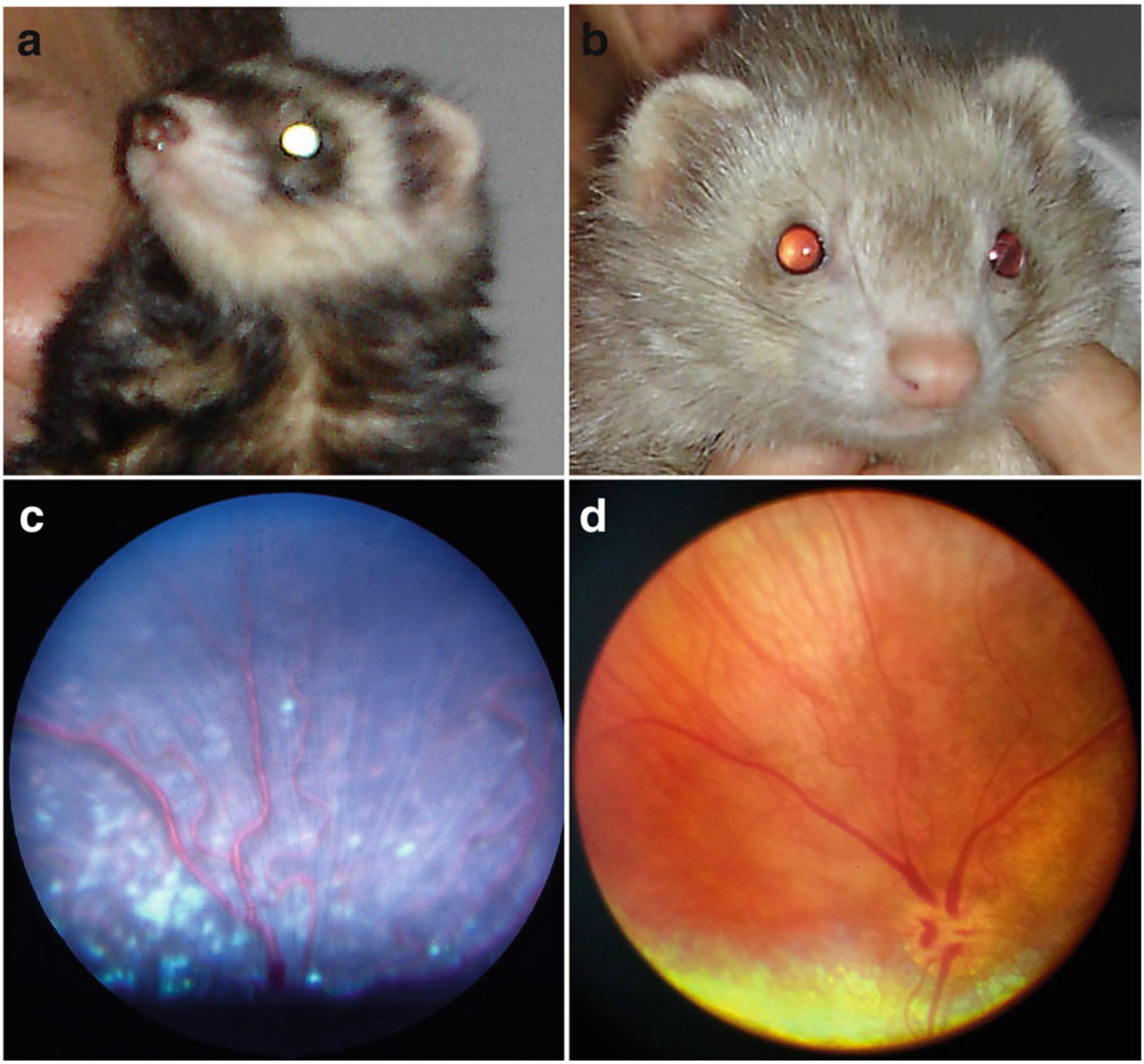

Fig. 39.2 Darkly pigmented ferrets possess a brightly reflective tapetum lucidum of variable size and color. (**a**) Note the *dark orange* reflex in this *blac*k-coated individual. (**b**) Note the presence of the holangiotic retina with a blueish tapetum lucidum in this young individual. (**c**) Note the small and poorly myelinated optic disc in this subalbinotic ferrets that lack melanosomes in the retinal pigment epithelium of the non-tapetal area and possess a tapetum lucidum of a *light yellow* to *orange color*. (**d**) (Courtesy Ana Carolina Rodarte de Almeida)

palatine, are found at the medial wall of the pterygopalatine fossa. Figure 39.3 provides an anatomic comparison of the orbit of two morphologic similar mustelids: the domestic ferret and the wild, free-ranging lesser grison *Galictis cuja*. In Spanish, the lesser grison is referred to as a huroncito (little ferret) or grisón. In Portuguese, this wild mustelid is called "furão selvagem" (wild ferret).

Ferrets possess a pronounced retrobulbar venous plexus that has been suggested as an alternative site for drawing blood (Fox et al. 1984; Good 2002; Davidson 1985; Wen et al. 1985). The authors do not recommend this procedure, since it is easier to collect blood from other locations and because of the possibility of damaging the globe with this technique. The clinical relevance for this observation is that hemorrhages from this venous plexus often occurs during enucleation procedures. If this happens, it should be carefully controlled by direct pressure, packing with gelatin sponges, or applying bovine thrombin at a concentration of 1000 IU/mL (Miller 1997; Williams and Gum 2013).

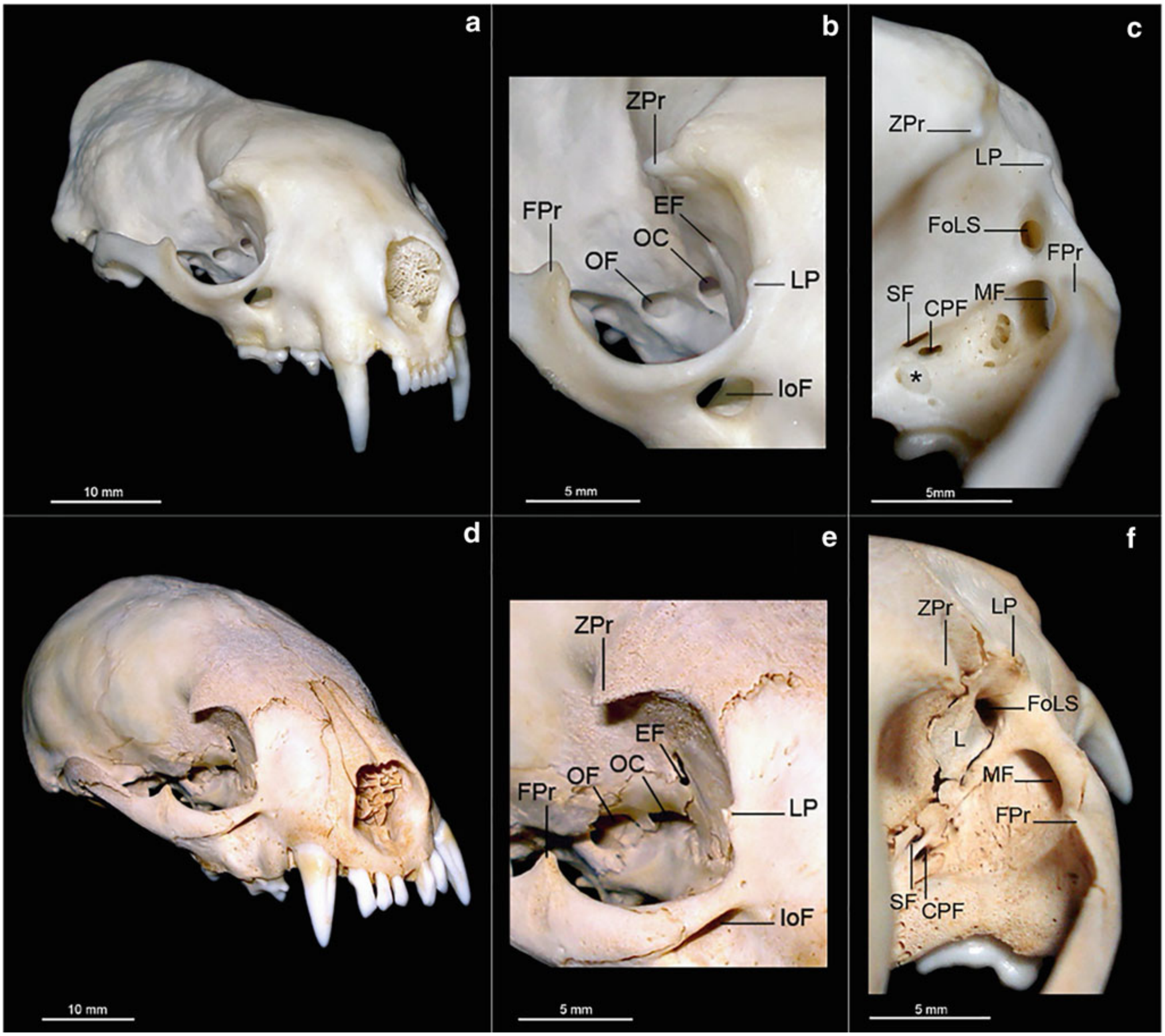

Fig. 39.3 Comparative anatomy of the bony orbit between a domestic and a wild mustelid. Views of an adult male domestic ferret (*Mustela putorius furo*) skull (**a**, **b**, and **c**) and of a male wild mustelid called lesser grison (*Galictis cuja*) skull (**d**, **e**, and **f**). (**a** and **d**) right rostrodorsolateral view of the two species; (**b** and **e**) close right rostrodorsolateral view of the orbit; (**c** and **f**) caudodorsolateral view of the orbit. *EF* ethmoidal foramen, *FPr* frontal process of the zigomatic bone, *IoF* infraorbital foramen, *L* lacrimal bone, *LP* lacrimal process, *FoLS* fossa for lacrimal sac, *MF* maxillary foramen, *OC* optic canal, *OF* orbitorotundum foramen, *PcF* caudal palatine foramen, *SF* sphenopalatine foramen, *ZPr* zigomatic process of the frontal bone. Note the exposure of the apical end of the root (*asterisk*) of the superior first (and unique) molar tooth through the pterygopalatine surface of the maxillary bone, on the floor of the pterygopalatine fossa. (Courtesy of Marcello Z. Machado)

Restraint and ophthalmic examination

Ferrets usually are fast and curious animals, which can make performing a complete ophthalmic examination a challenge. Other individuals may be quieter and calm and some may be even aggressive. Scruffing is the most common way of physically restraining ferrets during ophthalmic examination. The person scruffing the ferret should support some of the animal's weight, in order to avoid applying too much pressure in the neck itself, and to prevent iatrogenic elevation of intraocular pressure (IOP). Breaks during periods of restraint may help to decrease stress of the patient.

The palpebral fissures in young ferrets do not accommodate the width of the standard 5 mm Schirmer tear tests strips. The standard strip, nevertheless, fits most adult ferrets (Fig. 39.4a).

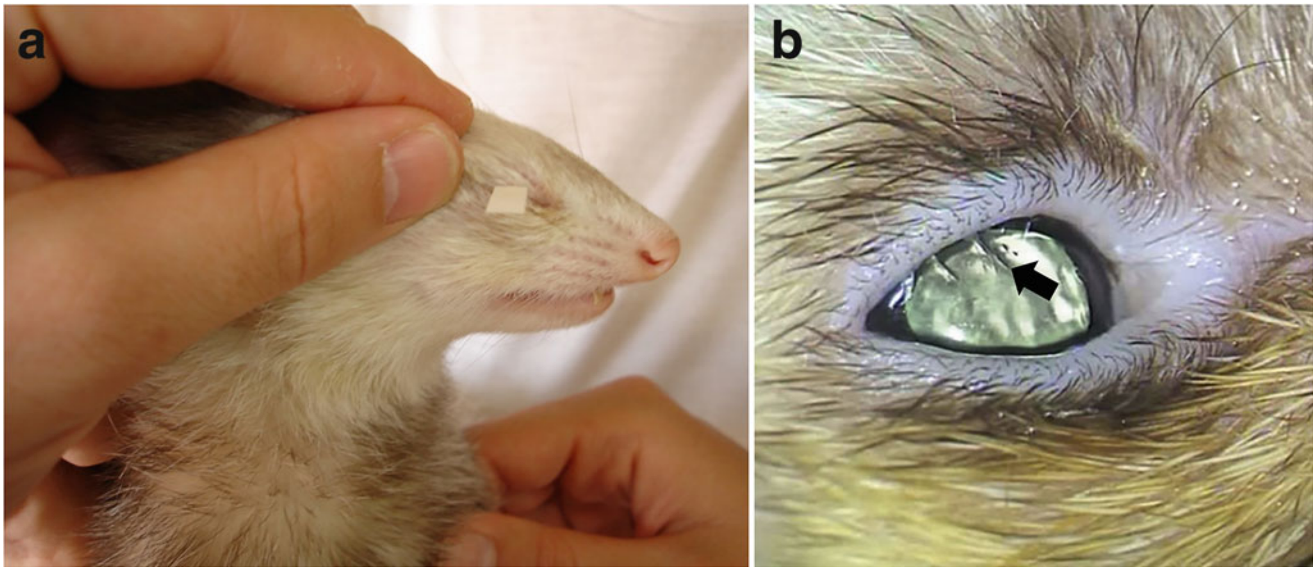

Fig. 39.4 (**a**) Note that the 5-mm Schirmer tear tests strip fits most adult ferrets (*arrow*). (**b**) Distichiasis in the right upper eyelid of a ferret. Note the three large distichia (*arrow*) in the upper eyelid of the right eye of a ferret with chronic epiphora and blepharospasm. Verboven CA, Djajadiningrat-Laanen SC, Kitslaar WJ, et al. Distichiasis in a ferret (*Mustela putorius furo*). Vet Ophthalmol. 2014;17:290–293

Ophthalmic Diseases

Eyelids

Entropion occurs due to the inversion of the eyelid margin (usually resulting in secondary trichiasis). It is a common ophthalmic condition in many domestic species and it has been documented in ferrets as well (Williams 2012). Anatomical (primary) entropion is the most common form in the ferret but it has been documented as a secondary condition due to conjunctival foreign bodies (Johnson-Delaney 2016). Serious corneal lesions can develop in some cases. Surgical correction requires most commonly the use of a modified Hotz-Celsus procedure. This involves excision of an ellipse-shaped stripe of skin parallel to the eyelid margin, the width, and length of which are dependent on the severity and extent of the entropion. Sutures of 6–0 polyglactin 910, silk, or braided nylon are frequently used to close the surgical wound.

Distichiasis has been diagnosed in ferrets (Verboven et al. 2014) (Fig. 39.4b). In this condition, cilia arise from Meibomian gland openings and both upper and lower eyelids can be affected. Animals with distichiasis must be evaluated carefully. The mere presence of distichiasis is not justification for surgical intervention. Treatment is indicated only when cilia are inducing corneoconjunctival irritation (ulceration, vascularization, fibrosis, pigmentation, epiphora, and/or blepharospasm). Possible treatment protocols include electroepilation or cryoelilation. Manual epilation is effective only temporarily but may aid in determining if the cilia are really causing a problem.

Congenital Ocular Conditions

Microphthalmia, cataracts, dermoids, and persistent fetal intraocular vasculature (PFIV) although uncommon, have been reported in the ferret (Miller 1997; Good 2002; Lipsitz et al. 2001; Kern 1989; Ryland and Gorham 1978). Microphthalmos has been reported in ferrets as part of an autosomal dominant multiple ocular anomaly syndrome (Dubielzig and Miller 1995) with cataract and retinal dysplasia (Williams and Gum 2013).

Neonatal Ocular Disorders

Ophthalmia neonatorum is a common condition in ferrets. A possible explanation for the relatively high prevalence is the long period of eyelid closure after bird. This disease occurs when an eye surface infection (often bacterial) occurs prior to lid separation. Clinically the eyelids appear distended (bulged) with or without the presence of external discharge. More than one individual in a litter frequently is affected. This disease is often diagnosed in kits aged a few days up to 3–4 weeks of age (Bell 1997; Good 2002; Williams 2012). Kits may stop nursing due to the pain related to pressing their head and eyes against the dam's nipple. It appears that *E. coli* mastitis in the jill may contribute to the disease development in kits (Besch-Williford 1987; Miller 1997; Good 2002). However, several other bacteria had been isolated in this disease. If possible, a sample of the exudate should be collected by aspiration or using a sterile swab and then submitted for culture and antimicrobial sensitivity tests. A feasible treatment option is to gently separate the eyelids (by cutting along the palpebral suture line by blunt dissection or by carefully with a small scalpel blade, then flushing the ocular surface and conjunctival sac with sterile saline. Subsequently start topical antibiotic therapy guided by the sensitivity test results or, when culture was not performed, a broad-spectrum antibiotic ointment such as bacitracin zinc + polymyxin B sulfate + neomycin sulfate, could be used instead, three to four times a day for 10–12 days. Possible sequelae include symblepharon, corneal perforation, and even blindness.

Eyelid Masses

Neoplasia is the most common cause of skin masses in the ferret. Ferrets can develop a wide variety of skin cancers including mastocytomas, histiocytomas, sebaceous gland adenomas and adenocarcinomas, basal cell tumors, lymphoma, leiomyomas, lipomas, fibromas, fibrosarcomas, and hemangiomas. Anecdotal reports of the occurrence of neoplastic disease in the skin of the eyelids of ferrets are somewhat common. Mast cell tumor has been diagnosed in eyelids of both eyes of a 6-year-old spayed female ferret (personal communication, 2019). Another case report describes the presence of an ulcerated 1–2 cm mass located at the lower eyelid margin of a 3-year-old ferret. Histopathologic diagnosis revealed a malignant fibrous histiocytoma (Dillberger and Altman 1989).

Conjunctivitis

Conjunctivitis is commonly seen in ferrets. Prognosis varies, depending on the etiology (Miller 1997). Unilateral conjunctivitis is often associated with foreign bodies whereas bilateral conjunctivitis can be caused by improper bedding due to accumulation of dust and debris in the tear film and conjunctival fornix (Moody et al. 1985) or by a primary bacterial disease (Gaarder and Kern 2001) and these have a good prognosis. Conjunctivitis also is commonly associated with systemic diseases in the ferret, such as distemper virus infection (Fig. 39.5), human influenza virus, erythema multiforme, salmonellosis, or mycobacteriosis (Miller 1997; Good 2002; Hernández-Guerra et al. 2007, Hoefer et al. 2012; Orcutt and Tater 2012. Distemper cases usually have a poor prognosis (Fig. 39.5) (Deem et al. 2000; Langlois 2005; Perpiñán et al. 2008; van der Woerdt 2012). Mortalities following canine distemper virus infection have been described also in colonies and wildlife populations of other mustelids, including martens (Fig. 39.5), polecats, badgers, ferret-badger, otters, and weasels, leading to the assumption that all members of the family are susceptible (Beineke et al. 2015). Influenza-related conjunctivitis has a good prognosis. There are reports of *Salmonella* species-related conjunctivitis in ferrets but these are often accompanied by fever and hemorrhagic diarrhea (Good 2002; Marini et al. 1989; Gorham 1949; Morris and Coburn 1948).

Bacteria can normally be cultured at low numbers from the conjunctival sac (as in most mammals commensal isolates usually are Gram positive) (Montiani-Ferreira et al. 2006). Secondary bacterial conjunctivitis is more common than primary disease and often results from a predisposing factor. Blepharospasm, ocular discharge, and conjunctival hyperemia are common clinical signs of bacterial conjunctivitis. Conjunctival cytological scrapings using the non-cutting end of a scalpel blade can help in the process of diagnosis, since neutrophils, bacteria, and white blood cells with intracellular bacteria are frequently observed in these cases (Gaarder and Kern 2001). For diagnosing influenza-related conjunctivitis virus isolation and serological titers are indicated. Topical triple antibiotic ointment (bacitracin zinc + polymyxin B sulfate + neomycin sulfate) 4–6 times a day is usually curative (Gaarder and Kern 2001).

The ophthalmic signs of distemper include mucopurulent oculonasal discharge, blepharitis (Fig. 39.5), corneal ulcers, ankyloblepharon, anterior uveitis, photophobia, and keratoconjunctivitis sicca (Miller 1997; Good 2002; Hernández-Guerra et al. 2007; Kern 1989; van der Woerdt 2012). Conjunctivitis with a mucopurulent ocular discharge develops in 7–10 days after being infected with the virus (Gaarder and Kern 2001) and occurs during the initial phase of the disease, along with anorexia, fever, and nasal discharge (Deem et al. 2000; Langlois 2005; Perpiñán et al. 2008; van der Woerdt 2012). During a distemper infection, conjunctivitis, and ocular discharge are a direct result of a decreased tear production and secondary bacterial infection. Other clinical signs the ferrets with distemper may present are erythematous skin rash, including the foot pads. Serum antibody titers or immunofluorescent antibody testing of conjunctival or blood smears can aid the diagnosis Affected ferrets usually die within 12–35 days postinfection a regardless of symptomatic therapy (Gaarder and Kern 2001).

Human influenza virus-related conjunctivitis in ferrets usually is self-limiting and runs its course in about 5 days even without treatment. However, it can be accompanied in some cases by pneumonia, complicating the clinical picture (Miller 1997; Gaarder and Kern 2001).

Systemic infection with *Mycobacterium genavense* has been reported to cause generalized lymphadenopathy and conjunctivitis in two ferrets (Lucas et al. 2000). Treatment is challenging and may include: chloramphenicol ophthalmic ointment, 3 times a day for up to 90 days associated with systemic rifampicin, clofazimine, or clarithromycin (Lucas et al. 2000).

In ferrets, conjunctivitis may be a consistent clinical sign in systemic mycoplasmosis (Williams and Gum 2013).

Conjunctival foreign bodies causing conjunctivitis and corneal irritation or ulcers are common. Gentle removal of the foreign body with forceps and treating the ocular surface with topical broad-spectrum antibiotics seem to be the best treatment protocol. Foreign bodies may penetrate through the conjunctiva leaving a sinus that discharges into the conjunctival sac. Treatment includes removal of the foreign body,

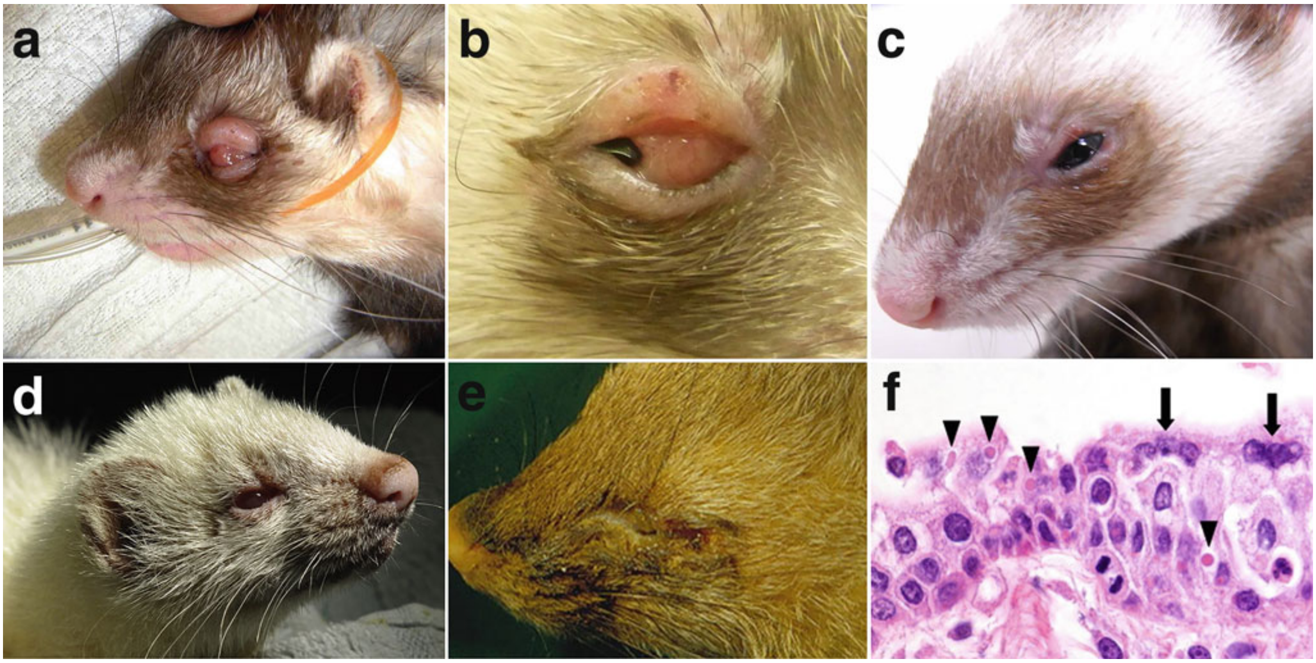

Fig. 39.5 Eyelid lesions in ferrets. (**a**–**c**) Multiple mast cell tumors of the eyelid and third eyelid of a 6-year-old spayed female ferret. Histopathologic analysis of biopsy samples from both locations on revealed multiple mast cell tumors. After oral prednisone administration, the eye lesions improved but recurred several weeks later. (**a**) Left eye at initial presentation. (**b**) Right eye at initial presentation. (**c**) Left eye 7 days after starting oral prednisone. (**d**) A case of conjunctivitis in a young ferret with a canine distemper virus infection. Note the oculonasal discharge, hyperemia, and blepharitis. (**e**) Canine distemper virus infection in a marten species. Note the presence of severe ocular discharge. (**f**) Photomicrography showing the conjunctival tissue with epithelial syncytial cells (*arrows*) and cytoplasmic eosinophilic viral inclusion bodies (*arrowheads*); hematoxylin–eosin, magnification ×600. (**a**)—Courtesy of Yasutsugu Miwa. (**d**)—Courtesy of Nicola Di Girolamo. (**e**, **f**)—Used with permission from: Beineke A, Baumgärtner W, Wohlsein P. Cross-species transmission of canine distemper virus-an update. One Health. 2015 Sep 13;1:49–59

surgical curettage, as well as treating with systemic and topical broad-spectrum antibiotics.

Corneal Diseases

Corneal Ulcers

A corneal ulcer is a lesion where there is a full-thickness defect in the corneal epithelium. The term can refer to a defect that just involves epithelium or one where there is loss of corneal stroma as well. Corneal ulcers are common in the ferret (Fig. 39.6), as it is for other species; the etiology is frequently multi-factorial, such as trauma, chemical irritants, eyelid defects (i.e., entropion and distichiasis), tear film defects, and secondary to corneal dystrophies and degenerations. Initial indications of the presence of corneal ulcers include an elevated third eyelid and corneal edema (Myrna and Girolamo 2019). The use of fluorescein dye (Fig. 39.6a, b) will demonstrate if the corneal epithelium has been ruptured and the stroma has been exposed. Fluorescein dye is also useful in assessing tear drainage via lacrimal puncta to the nares.

A broad-spectrum antibiotic (e.g., triple antibiotic solution) should be instilled q 6 h. It is important that the corneal ulcer specifically, the underlying abnormality or a given predisposing factor. If the response to treatment is not adequate, it is recommended to re-evaluate the diagnosis.

A topical parasympathetic blocking agent such as a 1% atropine solution, once a day for about 3–5 days, can be added to the protocol if iridocyclospasm is present. Culture and sensitivity tests can be used to direct the antibiotic choice. Chronic non-healing ulcers (also known as indolent ulcers or recurrent erosions) may necessitate an additional corneal epithelium debridement procedure with a cotton swab or diamond burr to promote corneal healing. Some serious ulcers are associated with a liquefaction (melting) of the corneal stroma. In this condition (melting ulcers) (Fig. 39.6c), corneal liquefaction (malacia) is caused by enzymatic (proteases) activity. The ulcer may rapidly (over hours) progress from a superficial to a deep ulcer. The enzymes originate from microorganisms (e.g., *Pseudomonas aeruginosa*, other Gram-negative rods, streptococci), PMN's, and from the cornea itself.

Deep or melting ulcers should be treated with surgery, usually a conjunctival pedicle graft technique, combined with aggressive antibiotic and anti-collagenase topical therapy (Montiani-Ferreira 2009).

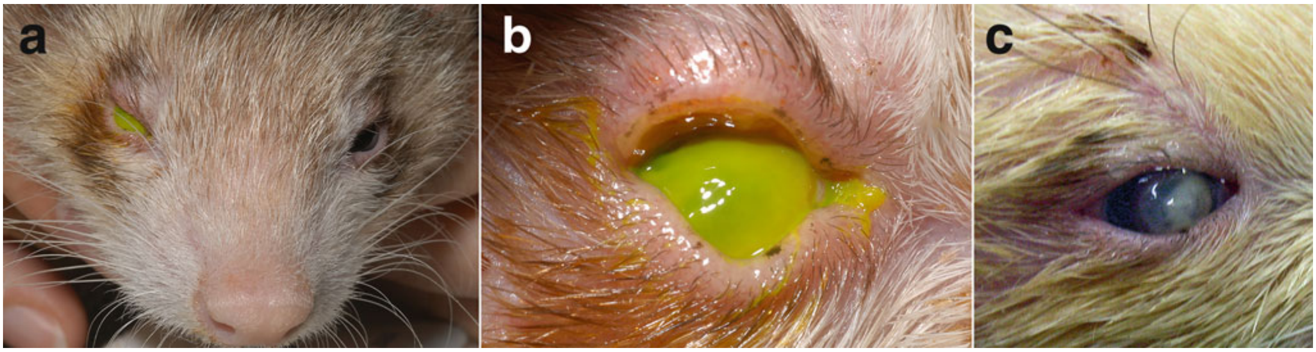

Fig. 39.6 A case of stromal ulcerative keratitis in the right eye of a ferret. Note the blepharospasm (**a**) and the fluorescein staining (**b**), demonstrating if the corneal epithelium has been ruptured and the stroma has been exposed. (**c**) A large corneal ulcer with an expanding white malacic gelatinous "melt." (Courtesy of Yasutsugu Miwa)

Other Corneal Diseases

Several other corneal diseases have been reported in the ferret and other mustelids. Intraocular disease can cause corneal edema and should be differentiated from corneal surface disease (Myrna and Girolamo 2019). Exposure keratitis secondary to exophthalmos has been reported (Miller and Pickett 1989; Good 2002). Ferrets with diets deficient in riboflavin were reported to develop corneal vascularization and opacification (Miller 1997; Good 2002). Degeneration of corneal endothelium leading to progressive corneal edema has been reported in mink (Hadlow 1987; van der Woerdt 2003). Some cases seem to respond to a symptomatic treatment using 5% sodium chloride solution, 2–4 times a day (van der Woerdt 2003; Montiani-Ferreira 2009).

Lymphoplasmacytic keratitis with multicentric lymphoma has been reported in a 2-year-old ferret (van der Woerdt 2003; Ringle et al. 1993). The keratitis in this ferret was unresponsive to topical steroids. In addition, systemic coronavirus was diagnosed in a patient with lethargy, weight loss, pruritus, and a yellowish corneal opacity (Lindemann et al. 2016). Anterior uveitis was evident in a similar fashion similar to cats with feline infectious peritonitis (Lindemann et al. 2016). The infiltrative corneal lesion in this ferret was similar to the corneal lesions described in a mink with Aleutian disease, a generalized parvoviral immune complex disease. The presence of antibodies against Aleutian Disease Virus (ADV) in ferrets is believed to increase susceptibility due to immunosuppression (Ringle et al. 1993). The mechanism by which ADV affects the immune system is not well-understood. Immunodepression could cause the ferret to be more vulnerable to viral enteritis, canine distemper virus, lymphoma, and other conditions. Degeneration of corneal endothelial cells leading to progressive corneal edema and cloudiness of the cornea is seen in older mink (8–11 years of age). Royal pastel females are predisposed. Unlike the disease in dogs, these mink do not develop corneal ulceration, pigmentation, or vascularization. There is no specific treatment for this condition, but symptomatic treatment with 5% sodium chloride solution or ointment two to four times a day may or may not improve corneal clarity (van der Woerdt 2012).

Congenital dermoids have been documented in the ferret showing the classic appearance of a patch of haired skin on the corneal surface (Myrna and Girolamo 2019).

Uveitis

Uveitis is not commonly diagnosed, even severe lens-induced uveitis (which is common in small animals); seems to be infrequent and mild when it happens. When the disease is diagnosed in the ferret, usually is secondary to trauma or ulcerative keratitis (reflex axonal pathway) (Miller 1997; Good 2002).

Aleutian disease might be considered in the differential diagnosis of ferrets presenting uveitis because experimentally induced Aleutian disease in minks produces uveitis as the primary ocular lesion (Miller 1997; Good 2002). Other causes of uveitis in ferrets include sepsis and neoplastic diseases, such as lymphosarcoma. If uveitis is present and a primary ocular origin cannot be found, diagnostic testing for systemic disease should be investigated (Good 2002). Thus, conjunctival cytology, complete blood count, serum biochemistry panel, urinalysis, thoracic radiographs, abdominal ultrasonography, PCR, and serology for infectious agents as well as other diagnostic testing modalities should be performed when uveitis is recognized in the ferret (Good 2002; Montiani-Ferreira 2009).

Topical steroids are used when corneal ulceration is not present. The frequency of application varies directly with the severity of the uveitis. Typically, it is applied 2–4 times a day. Lens-induced uveitis can usually be controlled with topical application of 1% prednisolone acetate 2 times a day (van der Woerdt 2003). Topical nonsteroidal solutions can be used with attention in cases of corneal ulceration as they have been associated in delay of corneal healing and promoting secondary infections. To relieve uveitis pain and to minimize the potential for posterior synechia in a miotic eye, topical atropine can be used typically once or twice a day. Its use is contraindicated when glaucoma is suspected (Montiani-Ferreira 2009). Systemic steroids at anti-inflammatory doses or nonsteroidal anti-inflammatory drugs (when steroids are contraindicated) still are the foundation of the treatment of uveitis (Montiani-Ferreira 2009) but the underlying cause should always be identified and treated.

Since glaucoma can be a blinding and painful sequela to uveitis, treatment for uveitis should be meticulous and anti-glaucoma therapy should be considered if intraocular pressure begins to increase (Good 2002).

Cataracts

Cataracts are somewhat common in ferrets. The incidence of cataracts in young ferrets may be as high as 47% in certain populations (Miller et al. 1993). Some young individuals may present cataracts associated with microphthalmos (Miller et al. 1993). The etiology of cataracts in ferrets, however, is not fully understood and may be multifactorial. Probable causes for cataracts include genetic and nutritional (Miller et al. 1993). Congenital cataracts and senile cataracts (Fig. 39.7) have been reported in ferrets (Good 2002; Bakthavatchalu et al. 2016). Clinically, most cataracts are seen in older ferrets (more than 5 years of age) (Fig. 39.7). Diets high in fat or deficient in vitamins, such as vitamin E, vitamin A and/or protein may lead to cataract formation in ferrets (Miller 1997; Good 2002). In addition to conjunctivitis and cataracts, vitamin A deficiency is reported to cause night blindness in ferrets (Fox and McLain 1998).

Successful surgical treatment of cataracts in ferrets using extracapsular or phacoemulsification technique has been reported (van der Woerdt 2003). Surgical planning needs to take into account that ferrets have small eyes and shallow anterior chambers. Primary and secondary lens luxations and subluxations can occur in ferrets (Miller 1997; Good 2002; Kern 1989). The condition is somewhat common, especially the ones secondary to chronic cataracts (Fig. 39.8).

Glaucoma

Glaucoma is actually a group of conditions and not a single disease entity. These conditions lead to an impairment of the aqueous humor outflow, which leads to an elevation of intraocular pressure (IOP) that is detrimental to axoplasmic flow in the optic disc resulting in retinal degeneration and blindness. Glaucoma in humans is very common; the commonest form in humans (primary glaucoma) is a chronic disease and causes a slow loss of visual fields. Both, primary and secondary glaucoma have been reported in ferrets. Fortunately, primary glaucoma is not very common in this species (Good 2002; Boyd et al. 2007). Glaucoma is a very painful condition and the eye quickly develops irreversible blindness. Thus, acute glaucoma is a medical emergency, and urgent action or referral to a veterinary ophthalmologist should be pursued. Unfortunately, glaucoma can be difficult to diagnose during the early stages without proper equipment and very difficult to manage successfully. Glaucoma also should be part of the differential diagnosis of the red eye and should be differentiated from uveitis and conjunctivitis. In fact, post-uveitis and post-synechia secondary glaucomas have been reported in ferrets (Good 2002; Boyd et al. 2007) (Fig. 39.9a, b). Secondary glaucoma as a result of anterior or posterior lens luxations also has been reported in ferrets (Miller 1997; Good 2002). In these cases, surgical extraction of the lens is feasible but somewhat difficult due to the small size of the eye (Good 2002). Intraocular neoplasia also can cause glaucoma in ferrets by infiltrating the drainage angle or by causing inflammation and adhesions (Fig. 39.9c, d).

Presently, veterinary ophthalmologists use three types of indirect (noninvasive) IOP estimations: indentation, applanation, and rebound tonometry. The two most frequently used types of tonometers are the Tono-Pen applanation tonometer (Fig. 39.10) and the TonoVet® rebound tonometer (Icare Finland Oy, Helsinki, Finland). Tonometry is essential in the diagnosis and treatment of glaucoma. Digital tonometry (palpating the eye with fingers to estimate "normal" versus "high" pressure) is inaccurate and should not be used to diagnose glaucoma or monitor response to treatment. The size of the cornea of adult ferrets is large enough to fit the tip of the applanation tonometer such as Tono Pen XL (Mentor, Santa. Barbara, CA, USA) (diameter = 3 mm) for intraocular pressure (Fig. 39.10). The rebound tonometer *TonoVet* (Icare, Oy, *Finland*) presents an even smaller probe (diameter = 1.3 mm) and the examiner can avoid the contact of the eyelids more efficiently (Leiva et al. 2006; DiGirolamo et al. 2013).

The normal values of IOP in the ferret as measured with a Tono Pen XL is 12–17 mmHg (Montiani-Ferreira et al. 2006) and 14.07 ± 0.35 as measured with a TonoVet (DiGirolamo et al. 2013). Normal IOP values, as well as other parameters for ophthalmic tests, are available in Appendix 3.

An increase in globe volume can take place with chronicity of glaucoma. This condition is called buphthalmos (Fig. 39.9) and when present usually indicates that the eye is irreversibly blind. In these cases, nucleation should be discussed with the owners.

To treat glaucoma in ferrets the use of topical β-blockers (0.5% timolol maleate), carbonic anhydrase inhibitors (2.0% dorzolamide), parasympathomimetic agents (1.0% pilocarpine), and prostaglandin analogues (0.005% latanoprost) have been reported. Alternatively, the use of a fixed combination of dorzolamide-timolol (Cosopt®, Merck & Co., Inc., Whitehouse Station, NJ, USA) one drop in the affected eye with an 8- or 12-h interval has been proposed (Montiani-Ferreira 2009). The efficacy of all these agents, however, still has not been completely proved in this species (Good 2002).

In most cases, medical treatment is only temporarily effective and will fail at some time. If glaucoma is not controlled permanently with medication, a surgical procedure might be

Fig. 39.7 Cataract in an older ferret. (**a**) A castrated male, 6-year-old ferret presenting bilateral cataracts, in the right eye (**b**) note the hypermature cataract and in the left eye (**c**) Note a Morgagnian hypermature cataract, formed by liquefaction of the cortex and sinking of the dense nucleus to the bottom of the capsular bag. (Courtesy of Adolfo Guandalini)

indicated. Diode laser has been used to perform a transscleral cyclophotocoagulation to control the pressure in one case of glaucoma in a 7-year-old neutered male ferret. The intraocular pressure was controlled with alternate-day application of a topical steroid after (Good 2002). Animals with glaucoma should be referred for surgical treatment of glaucoma, when there is still some hope of vision. Early referral or emergency referral should always be considered when dealing with glaucoma. Once the eye is irreversibly blind, the animal's comfort is the main consideration.

Retinal Atrophy

Progressive retinal atrophy (PRA) has been anecdotally reported in ferrets (Gaarder and Kern 2001; Williams and Gum 2013). PRA is a collective term used to describe several hereditary retinopathies that are similar clinically. Since this disease initially targets rods that function in dim light and are most abundant in the peripheral retina, nyctalopia, and poor peripheral vision initially occur but may not be noticed until the disease is advanced. Progressive loss of day vision follows. Eyes appear "brighter" because tapetal reflectivity

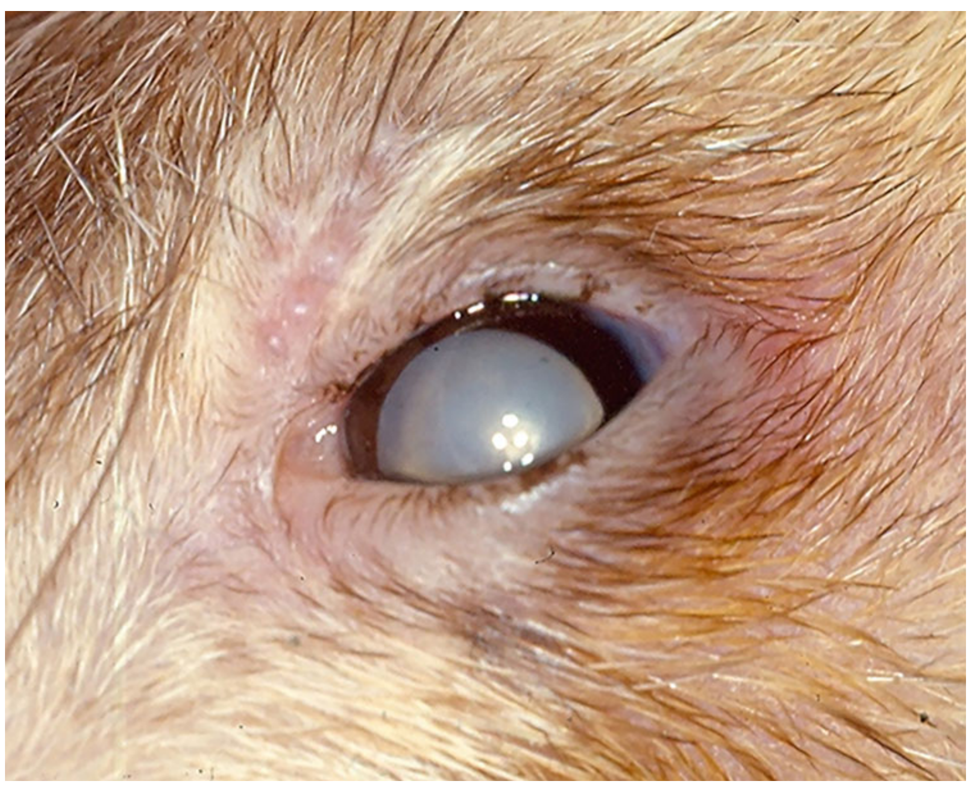

Fig. 39.8 Anterior lens luxation secondary to chronic cataracts in the left eye of an adult male ferret. (Courtesy of Adolfo Guandalini)

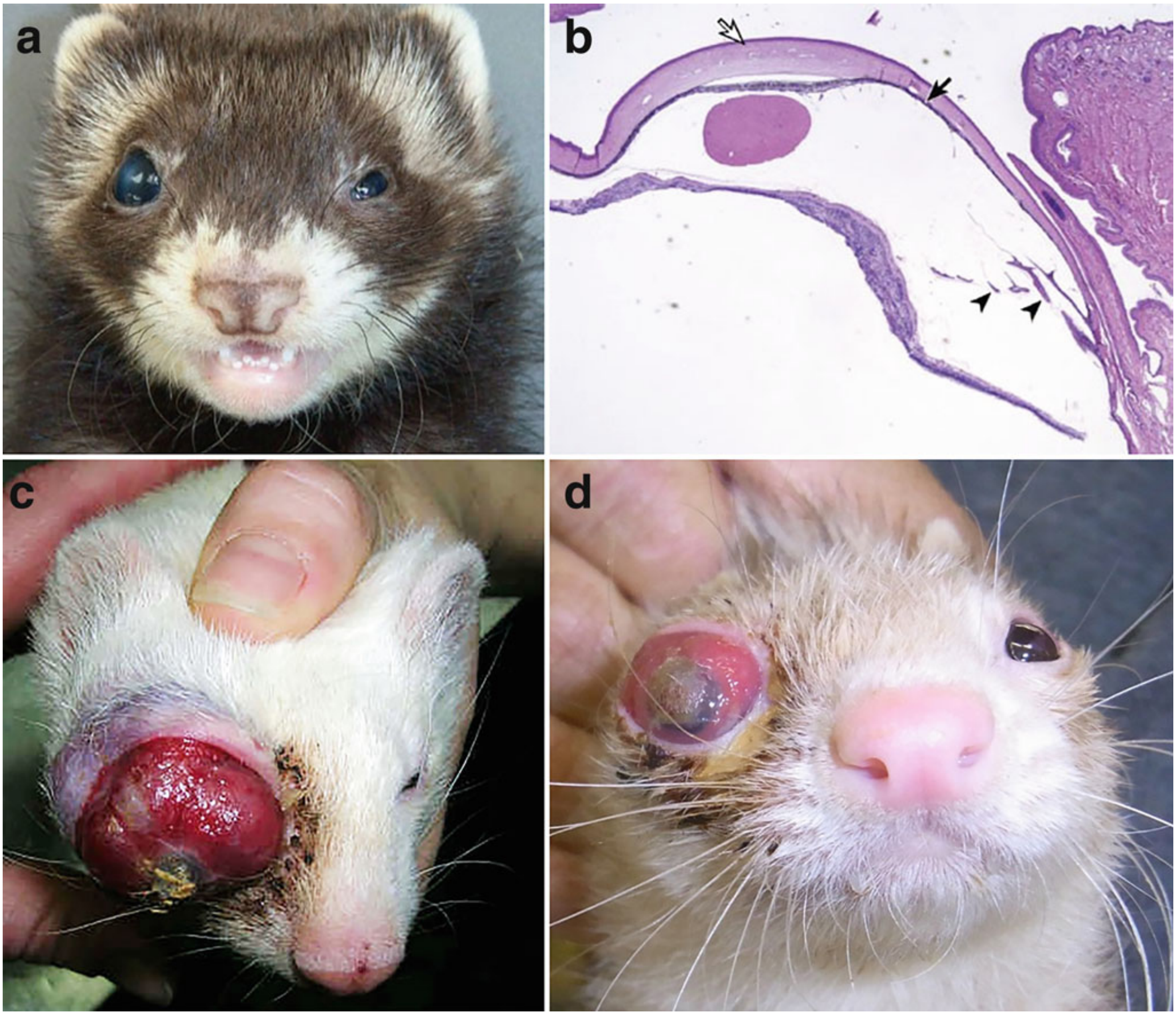

Fig. 39.9 Chronic secondary glaucoma cases presenting buphthalmos. (**a**) An 8-week-old male ferret with mild buphthalmos due to secondary glaucoma. (**b**) Low-power photomicrograph of the whole anterior segment of the same right eye (as in **a**). The white arrow indicates the cornea at three times the normal thickness with numerous (abnormal) corneal blood vessels. Peripherally the iris is attached to the cornea resulting in broad anterior synechiae (*black arrow*). *Black arrow* heads point to retracted ciliary processes. It is likely this ferret had secondary glaucoma caused by synechial-induced obstruction of the aqueous humor drainage system. (**c** and **d**) are representative cases of ferrets presenting more severe buphthalmos and forward displacement of the globe. In both cases, the condition was believed to be due to an intraocular neoplastic disease. In addition, in both of these cases, the owners were scheduled for bringing the patients for enucleation and failed to show up for the surgery. Thus, a definitive diagnosis was never reached. (**a**, **b**) Boyd K, Smith RS, Funk AJ, Rogers TD, Dobbins RM. A closer look: secondary glaucoma more likely. Lab Anim (NY). 2007;36(1):13–14 (with permission). (**c**) Courtesy of Angela Duke. (**d**) Courtesy of Yasutsugu Miwa)

is increased and pupils tend to remain dilated. Often first discovered by the owner when dog is taken to unfamiliar surroundings. Cataracts may or may not be present (van der Woerdt 2003). Increased tapetal reflectivity, granular texture to tapetum lucidum, depigmented non-tapetal fundus, attenuation of retinal blood vessels, demyelinated optic papilla, decreased pupillary light reflexes (particularly late in disease), and mydriasis also are common clinical features. Secondary cataracts may develop concurrently particularly in the later-onset forms. Genetic factors and nutritional (e.g., taurine and vitamin A) deficiencies have been suggested in different reviews but not reported in the primary literature are being investigated (Gaarder and Kern 2001; Good 2002; Williams and Gum 2013). Since there is no effective cure clinically available for this condition, the affected animals should be removed from breeding programs.

Fig. 39.10 An applanation tonometer (Tono-Pen XL, Mentor, USA) being used in the left eye of an adult ferret. Note that the size of the cornea of adult ferrets is large enough to fit the tip of the applanation tonometer

Exophthalmos

Exophthalmos is a pathological rostral protrusion of a normal-sized globe within the orbit. Retrobulbar diseases are occasionally seen in ferrets causing exophthalmos. Other clinical signs of retrobulbar disease include protrusion of the third eyelid and examiners' failure to retropulse the eyeball. There are case reports in the literature and several cases submitted to the Comparative Ocular Pathology Laboratory of Wisconsin (COPLOW) (Dubielzig, personal communication, 2019) of zygomatic salivary gland mucocele and orbital neoplastic disease (such as lymphosarcoma) causing exophthalmos in ferrets (Fig. 39.11) (Miller and Pickett 1989; McCalla et al. 1997; van der Woerdt 2003). Ultrasonography and fine-needle aspiration of the retrobulbar space followed by cytology may help diagnosing the exophthalmos-causing condition. Other diagnostic imaging modalities also may help, such as computed tomography scan and magnetic resonance.

Otters

There are 13 species of otter in the subfamily Lutrinae distributed across the globe. Most of the otters are insufficiently known, and most are rapidly disappearing along with the clean wetlands they inhabit worldwide. The IUCN Red List of Threatened Animals (IUCN 1988) lists eight otters as either "Vulnerable" or "Insufficiently Known." The five "Vulnerable" species include the marine otter (*Lutra felina*), Neotropical otter (*L. longicaudis*), giant otter (Pteronura brasiliensis) of South America, and the Eurasian otter (Lutra lutra) in Europe and northern Asia. In Asia, the Asian small-clawed otter (*Aonyx cinerea*), smooth otter (*Lutra perspicillata*), and hairy-nosed otter (*L. sumatrana*) are listed as "Insufficiently Known" (Foster-Turley et al. 1990).

Otters are amphibious (sea otters) or semiaquatic (river otters) carnivorous mammals who must adapt their visual processes to survive in both an aquatic environment and a terrestrial environment. They must see well in both environments as they mostly feed and breed in the water, including different water depths up to about 100 m (Bodkin et al. 2004). While sea otters can spend their entire lives in the water, they will keep their heads above water throughout the day and need to have an acute vision in both air and water. Sea otters, specifically Southern sea otters (*Enhydra lutris nereis*), are listed as a threatened species under the ESA. Threats to their livelihood historically included the fur trade and more recently include climate change/pollution, predation, and loss of their prey species the sea urchin, among other causes. They are a keystone species and sentinel animal of ocean health and one of the only marine animals to use tools as devices, which they use to open shells of mollusks such as mussels while foraging. In addition to the below-mentioned ocular adaptations to a marine environment, otters have developed long whiskers for sensation in murky waters and the densest fur of any mammal, allowing for survival

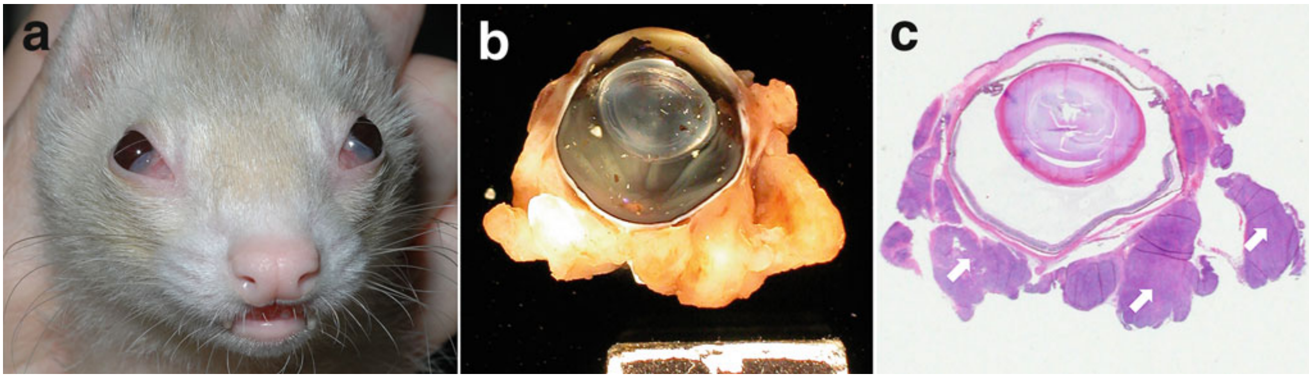

Fig. 39.11 An example of lymphosarcoma as a retrobulbar disease-causing exophthalmos. Note the rostral protrusion of a normal-sized globe and the protrusion of the third eyelid (**a**). Gross anatomy (**b**) and histologic (**c**) aspects of an enucleated globe diagnosed. Note the retrobulbar hypercellular proliferation causing compression of the globe. (Courtesy of Richard Dubielzig, Comparative Ocular Pathology Laboratory of Wisconsin (COPLOW))

without blubber in cold temperatures. Some of the ocular adaptations involve the cornea, lens, and accommodation. In a terrestrial environment, the cornea provides a significant amount of refractive power, bending light to focus on the retina because of the refractive indices differences between air and the cornea. In water, however, this corneal refractive power is lost due to the refractive indices of water and the cornea being very similar. For this reason, otters have to have a mechanism to adjust to vision in both environments. Both sea and river otters do this in a manner similar to some aquatic birds, with lens anterior movement allowing for an accommodative range of 60 D for the sea otter (Murphy et al. 1990; Ballard et al. 1989).

Morphological Features of the Globe and Orbit

In the same way as ferrets, the otters' bony orbit is incomplete. Using fixed globes, the horizontal limbal diameter was measured at 9 mm and the vertical diameter was 8 mm. The axial diameter of the globe was about 14 mm and equatorial diameter was 14.5 mm (Murphy et al. 1990). An image of a normal otter eye can be found in Fig. 39.12.

Otters possess a corneoscleral venous plexus within the sclera. The axial cornea is nearly 0.3 mm thick with very developed anterior epithelium composed of a layer of basal cells than a couple of layers of wing cells and about a dozen layers of superficial squamous cells. The stroma is 0.2 mm thick and has regularly aligned lamellae. Similar to other mammals, there is a thin Descemet's membrane and a posterior layer or endothelium with cuboidal cells (Murphy et al. 1990).

The iris stroma is mostly smooth muscle fibers. There is a circumferential smooth muscle sphincter extending from within 1 mm of the iris root to the pupillary margin. The radial iris dilator muscle occupies most of the iris extending from the root to within 0.2 mm of the pupillary margin. Otters also have an oblique smooth muscle fiber at the iris root and a well-developed ciliary muscle that is smooth muscle in composition (Murphy et al. 1990).

Otters have been shown to dilate partially with tropicamide. Anesthesia, particularly opioids, can counteract this, so dilating for a procedure such as cataract surgery can be challenging depending on the anesthetic used. Multiple drops may be needed including tropicamide, phenylephrine, and if intraocular surgery, epinephrine, and viscoelastic. Figure 39.13 shows an otter eye after receiving multiple drops of tropicamide versus the same otter the following day once the effects have worn off. As can be observed in Fig. 39.13a, a minor pharmacological dilation did occur, but more would be needed for a surgical procedure.

The lenses from fixed samples measured 7.4 mm. Unlike other marine mammals, otter lens anatomy is more similar to their terrestrial relatives and the rest of the *Mustelidae* family and they maintain a lenticular shaped lens rather than a spherical lens (Mass and Supin 2000). The retina is holangiotic (Fig. 39.14) with vessels extending throughout the retina and onto the optic nerve head, similar to other mustelids. The otter retina (*Enhydra lutris)* has three different opsins (Rod, M/L cone, S cone) (Levenson et al. 2006). There is an extensive cellular-type tapetum located in the choroid. Similar to terrestrial retinas, the otter retina has a nasotemporal area of high density of ganglion cells, or a visual streak, where there are relatively small and dense cells about 4000 cells/mm^2 (Mass and Supin 2000).

Vision an Optics

Anatomical and behavioral studies suggest that sea otter visual acuity is comparable although underwater acuity is possibly slightly worse than other marine mammals (Mass

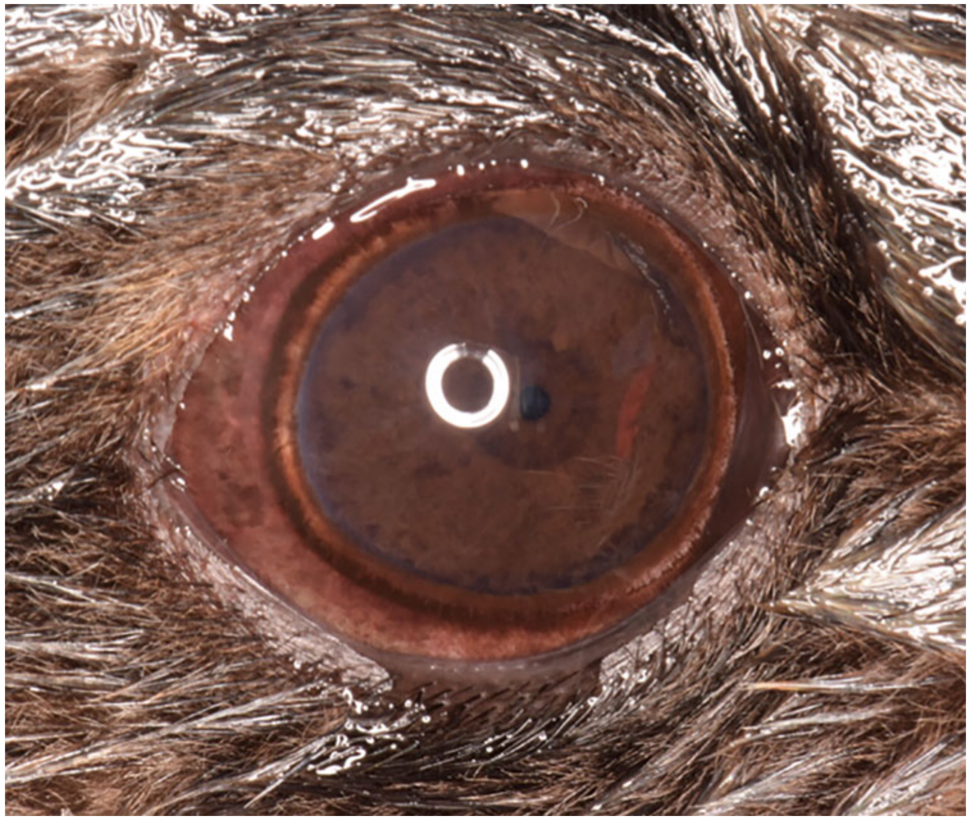

Fig. 39.12 Image of normal sea otter (*Enhydra lutris*) eye. (Image courtesy of K. Freeman and taken under USFWS MA 186914–2)

and Supin 2000; Gentry and Peterson 1967). The accommodative range of the otter is reported to be 3–4 times greater than any terrestrial mammal (Walls 1967). The sea otter and the Asian clawless otter both maintain equivalent visual acuities in air and water (Schusterman and Barrett, Ballet and Schusterman). They use the refractive

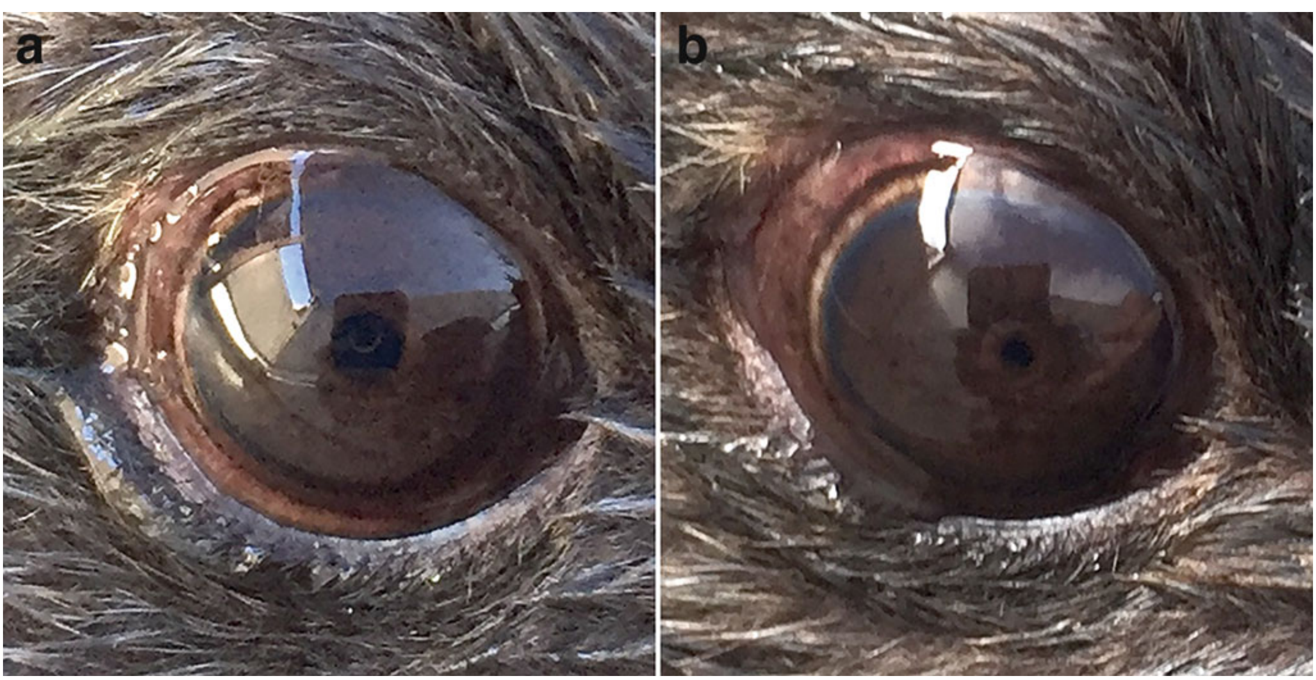

Fig. 39.13 Pupil dilation in otters. (**a**) Sea otter (*Enhydra lutris*) eye post-tropicamide. (**b**) Same otter eye 24 h following dilation

Fig. 39.14 Holangiotic retina of a normal sea otter (*Enhydra lutris*) eye. (Image by K. Freeman taken under USFWS MA 186914–2)

power of the curved cornea and lens, similar to other *Mustilidae* in air (Balliet and Schusterman 1971). The special adaptations are useful for water acuity where they have adapted to develop a large accommodative range similar to what cormorants accomplish with a very large movement and lens curvature change. This probable lens curvature change likely occurs with the aid of the iris and iris musculature forming a ring through which the lens is squeezed and moved anteriorly. A proposed mechanism in the sea otter involves the ciliary muscles, which may aid to move the ciliary body anteriorly and dilate the inner wall of the corneoscleral venous plexus, thereby causing an outflow of aqueous from the anterior chamber and an influx into the posterior segment, which would further propel the lens anteriorly. Murphy et al. 1990 also proposed that the unique uveal-uveal fibers contraction could draw the root of the iris posteriorly and the ciliary body anteriorly, further helping to move the lens anteriorly.

Ophthalmic Diseases

Corneal ulcers are approached similarly to those in ferrets and other carnivores. Ulceration from flaking mineral/lipid due to corneal degeneration/dystrophy has been diagnosed in an Asian small-clawed otter *Aonyx cinereus* (Bret A. Moore, personal communication). The right cornea was mildly affected axially (Fig. 39.15a), however, the left eye developed a deep facet with continued ulceration from ruptured epithelial bullae secondary to suspected endothelial decompensation (Fig. 39.15b, c). A conjunctival pedicle graft was elected to (1) provide stability over the deep corneal defect, and (2) act as an active source of edema removal from the corneal stroma (Fig. 39.15d). The graft was prepared very thin, and was secured onto the cornea with 10–0 Polyglactin 910 absorbable (Vicryl) following debridement of the epithelium within the defect.

Keratitis initiating at the lateral aspect of the cornea has been reported in otters. The origin of this is yet unknown but it is possible it is similar to a pinniped keratopathy and may have either an autoimmune or UV-induced or combination of both causes. Figure 39.16 shows an example of lateral keratitis. Figure 39.16a shows the pre-treatment corneal appearance and 16b shows continued fibrosis but more hypoperfused vessels post-NSAID treatment.

Otters in captivity have been shown to develop cataracts. Like other species, cataracts are likely due to a variety of causes including age-related, UV related, inherited, and metabolic/drug induced. Anecdotal evidence indicated that steroid use in cases of immune-mediated diseases has been linked to cataract development. Cataract surgery can be successfully performed with phacoemulsification. The lenses have been subjectively reported to be relatively soft and to aspirate easily with a short phacoemulsification time. Cataracts themselves can cause lens-induced uveitis and topical anti-inflammatory medications are needed when the cataracts are advanced and either late immature, mature, or hypermature. Figure 39.16a shows a mature cataract in a partially dilated sea otter and Fig. 39.16b is the same eye with the pupil not dilated. Figure 39.17a shows a mature cataract causing lens-induced uveitis in a partially dilated sea otter. Figure 39.17b is the same eye after treatment with topical ketorolac twice a day for a month showing resolution of the lens-induced uveitis.

Otters with systemic disease can develop anterior uveitis and/or corneal edema. For example, there was a case in Scotland of a wild malnourished Eurasian otter who developed bilateral corneal edema about 2 weeks after being admitted to a rehabilitation center. This otter died about 10 days later of *Clostridium piliforme* infection, Tyzzer's disease. While the iris appeared to have no more leukocytes than a normal iris, there was marked inflammation in the cornea and posterior cornea, including endothelium (Simpson et al. 2008). Uveitis involving the iris and ciliary body has also been reported in otters naturally infected with Aleutian Disease Virus (ADV) (Williams 2012).

Otters infected with the fatal parasite *Sarcocystis neurona* can have retinal damage starting at the retinal pigment epithelium and throughout all layers of the retina. In one case, this included damage to the inner and outer nuclear layers. In this same case, the damage was worse at the outer retina and inner surface of the tapetum. There was also hemorrhage in the choroid and vitreous. *S. neurona* causes a protozoal

Fig. 39.15 Corneal degeneration/dystrophy in an Asian small-clawed otter (*Aonyx cinereus*). (**a**) Mild axial corneal degeneration without complication. (**b**, **c**) Corneal mineral or lipid deposits sitting with a deep facet with several pinpoint ulcerations due to ruptured bullae. Note the severe corneal edema, thought to be due to endothelial decompensation. (**d**) A conjunctival pedicle graft was successfully placed, providing tectonic support as well as drawing fluid from the edematous stroma. (Courtesy of Bret A. Moore)

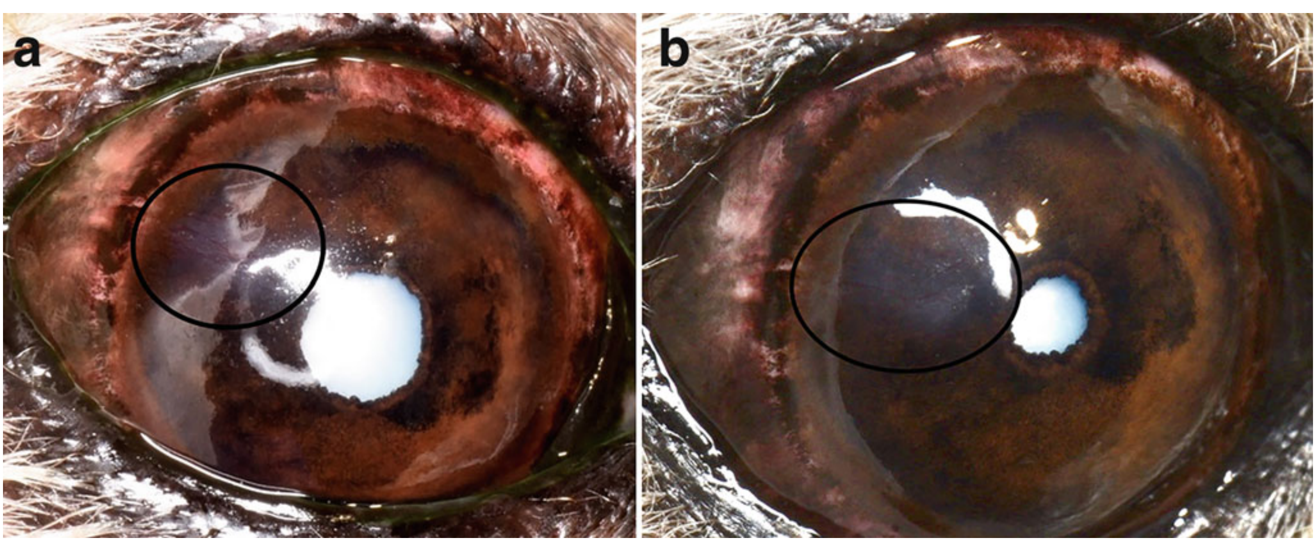

Fig. 39.16 Lateral keratopathy including vessels and fibrosis in older sea otters (*Enhydra lutris*). (**a**) is pre-treatment where more active inflammation can be seen and (**b**) is post weeks of ketorolac where reduced inflammation (hypoperfused vessels, less hyperemia) can be seen. In addition is possible to see a mature cataract in partially dilated otter (**a**) with mild LIU, best seen as conjunctival and episcleral injection. (**b**) Mature cataract, undilated eye treated with ketorolac. Note less conjunctival and episcleral injection

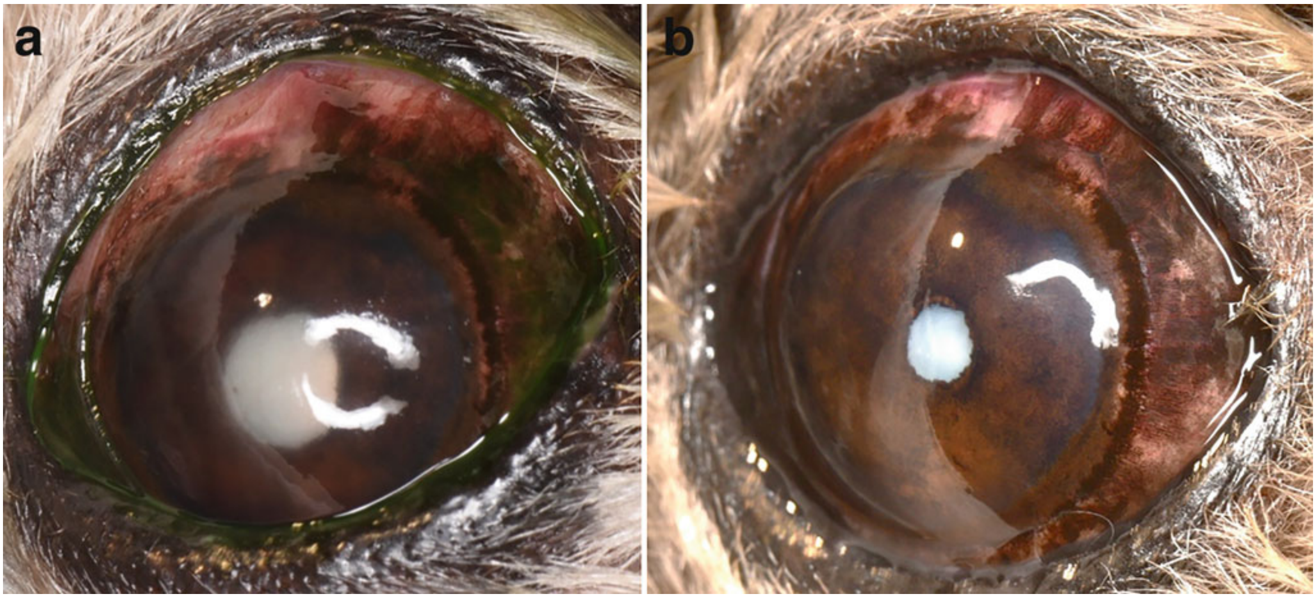

Fig. 39.17 Mature cataract with lens-induced uveitis in a sea otter (*Enhydra lutris*). (**a**) Note the hazy appearance of the pupillary margin obscured by flare and cell. Pigment on ALC also noted (**b**) is the same eye treated with ketorolac and undilated pupil. Note the much clearer anterior chamber and now well-defined pupillary margin

meningoencephalitis that does not always, but can have chorioretinal involvement. Pinnipeds have been successfully treated with ponazuril at 10 mg/kg for 3 months (Mylniczenko et al. 2008).

The finding of free-ranging blind otters appears to be relatively common (Williams 1989). A case of sudden reported blindness in a river otter Neotropical Otter (*Lontra longicaudis*) from the Curitiba Zoo (Brazil) was recently seen. During the examination, the animal appeared bright but not detectable menace response. No significant lesions were observed in the globe or adnexa. Pupillary reflexes were normal. A mini portable Ganzsfield (HMsERG model 1000, Ocuscience®, Michigan, USA) was used to perform the flash electroretinogram (FERG). ERGs were performed using chemical restraint isoflurane delivered by mask. The otter was placed in sternal recumbency with the active electrode (ERG-Jet, Fabrinal SA, La Chaux-de-Fonds, Switzerland) positioned on the cornea and hypodermic platinum needles (Model E2, Grass Technologies, Warvick, USA) positioned as reference and ground electrodes. The reference electrode was positioned about 2 cm from the lateral canthus, and the ground electrode was positioned at the base of the neck. The protocol used was a short protocol, consisting of light flash intensities of 10 mcd.s/m^2, 3000 mcd.s/m^2, and 10,000 mcd. s/m^2. a- and b-wave amplitudes, and implicit times (ITs), were measured by ERGVIEW 4.380 V software (Ocuscience®, Michigan, USA). Electroretinographic responses seemed compatible with normal retinal function (contained a- and b-waves with adequate amplitudes and implicit times) (Fig. 39.18). A presumptive diagnosis of central blindness was given at the time. On the same night of the examination, the otter had several seizures and died. At necropsy, a lesion compatible with occipital lobe infarction was observed (Fig. 39.18) confirming the suspicion of central blindness.

Very little is known about the giant otter, *Pteronura brasiliensis*, besides being the longest member of the Mustelidae family, endemic to wetlands and river systems in forests of South America (Eisenberg 1989). Vision has not been studied in detail yet, but it is known that the animal has large eyes and long whiskers to help detect prey in the water, with and nostrils and ears that close in the water. The giant is exclusively active during the day and hunts by sight and rest in their burrows at night. Giant Brazilian Otters are piscivores (prefer to eat fish), but when fish supplies are low they will also hunt crustaceans, small snakes, and small caiman (Wilson and Mittermeier 2009). There are several anecdotal reports of eye diseases observed in giant otters in the wild. One animal has been seen with phthisis bulbi apparently thriving in the Pantanal wetland, Brazil (Fig. 39.19).

Other members of the Musteloidea superfamily (red pandas, raccoons, coatis, kinkajous, olingos, olinguitos, ringtails, cacomistles, skunks, and stink badgers).

Compared to the members of the Mustelidae family, relatively little is known about the eye as well as its role in health and disease of the members of Ailuridae, Mephitidae, and Procyonidae families. Musteloids share diseases between species, such as mustelid herpes virus, canine distemper, and infectious hepatitis viruses, along with a range of nematodes and protozoans presenting a contagion risk when

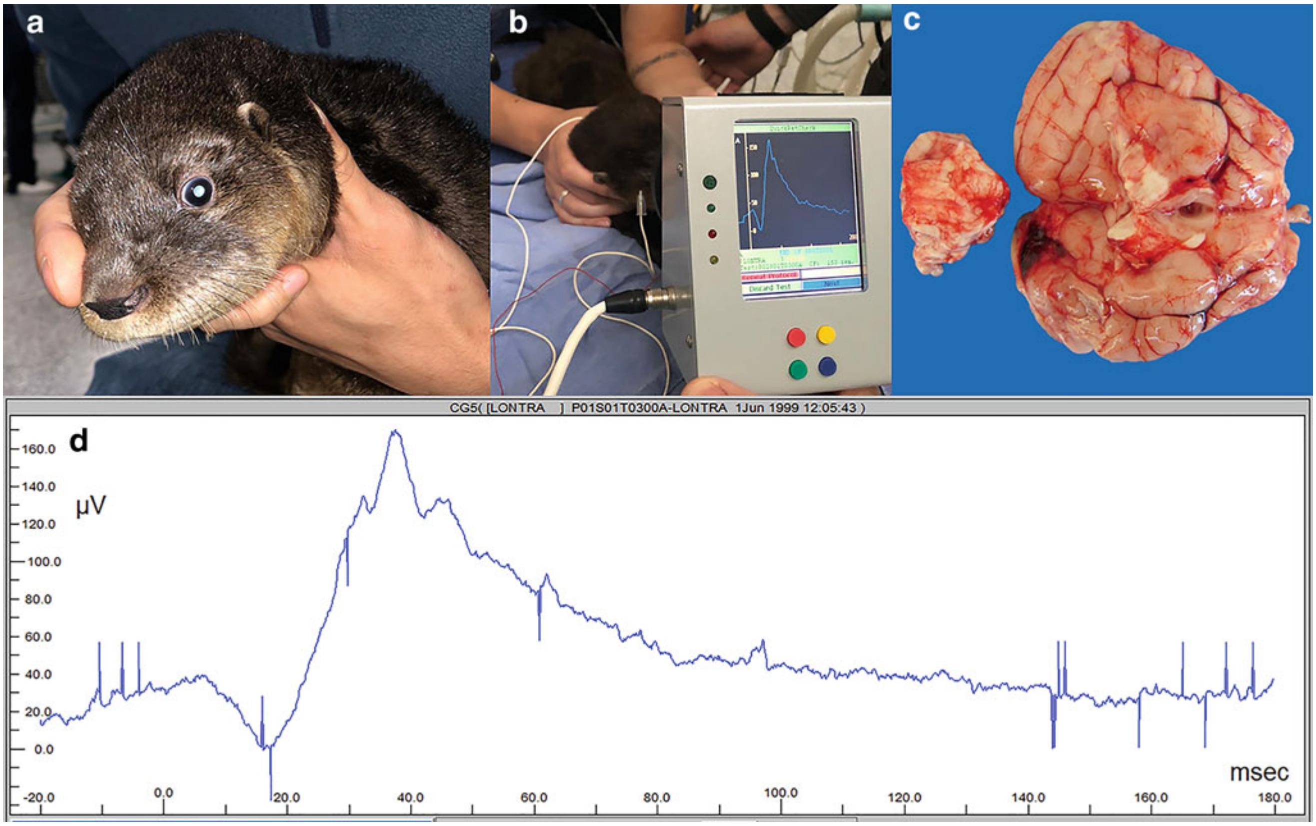

Fig. 39.18 A river otter from the Curitiba Zoo was examined with the chief complaint of blindness. No lesion was detected in the globe (**a**) and retinal function was not impaired based on electroretinographic results (**b**, **d**). On necropsy, a large area of parenchymal hemorrhage on the occipital lobe (**c**). (Image by Fabiano Montiani-Ferreira)

vulnerable musteloids are being conserved or reintroduced. Skunks and raccoons are major rabies hosts in North America and because both are considered synanthropic species, they can pose substantial zoonotic risks (Newman and Byrne 2017). In addition, raccoon roundworm larvae (*Baylisascaris procyonis*) should be considered as a probable cause of cular larva migrans and diffuse neuroretinitis in humans (Kazacos et al. 1985).

Red Pandas

The red panda (*Ailurus fulgens*) is an arboreal mammal species native to the eastern Himalayas and southwestern China. They eat mostly bamboo, but also may occasionally eat small mammals, birds, eggs, flowers, and berries. In captivity, they were observed to eat birds, flowers, maple and mulberry leaves, and bark and fruits of maple, beech, and mulberry (Roberts and Gittleman 1984; Panthi et al. 2015).

The red panda cubs start to open their eyes at about 18 days of age. After about 90 days, they achieve full adult fur and coloring and begin to venture out of the nest. They also start eating solid foods at this point, weaning at around 6–8 months of age. Conjunctivitis in newborn cubs delaying the eyelid opening, called ophthalmia neonatorum, has been observed in a patient with signs of ocular and respiratory infection (Fig. 39.20).

Red pandas are known to be highly susceptible to canine distemper virus (Deem et al. 2000; Qin et al. 2007) and to a number of protist and helminth disease-causing organisms from domesticated companion animals, including *Toxoplasma gondii*, *Neospora caninum*, and heartworm infections with *Dirofilaria immitis* (Lan et al. 2012). In addition, ascarid nematodes such as *Baylisascaris ailuri* (Xie et al. 2011) and several genera of metastrongylid nematodes such as *Angiostrongylus vaso*rum (Patterson-Kane et al. 2009) have been strongly implicated in inducing pneumonia and visceral, ocular, and neural larval migrans in red pandas.

It is believed that both its arboreal lifestyle and plant-based diet may have been contributing factors to the development of fungal keratitis, which was already reported in this species (Volk et al. 2018). Fungal keratitis was diagnosed and treated in two captive red pandas at a zoo in Melbourne, Australia (Fig. 39.21).

Fig. 39.19 A giant other with phthisis bulbi in its left eye, captured in this picture while eating a fish. (Courtesy of Nathalie Foerster and Grazielle Soresini, Brazil)

The diagnosis of fungal keratitis was confirmed with either cytology or histopathology. Severe unilateral ocular pain and stromal abscessation were observed. A superficial keratectomy was performed in both cases. Following surgery, a combination topical (topical silver sulfadiazine ointment), subconjunctival (atropine) as well as systemic medical therapy that included oral doxycycline (25 mg PO BID), carprofen (10 mg PO), and fluconazole (50 mg PO SID), contributed to a successful outcome (Volk et al. 2018). Bamboo-related trauma leading to the development of keratomycosis has been reported in humans (Gopinathan et al. 2002; Lin et al. 2005; Lan et al. 2012; Qiu and Yao 2013).

Raccoons

The presence of bushy ringed tails is an outstanding anatomical feature of raccoons. The most common species is the North American raccoon (*Procyon lotor*), also called common raccoon or northern raccoon, which ranges from northern Canada and most of the United States southward into South America. It has a noticeable black "mask" around the eyes and the tail has 5–10 black bands. The other two most common species of raccoon are the Crab-eating raccoon (*P. cancrivorus*) and the Cozumel raccoon (*P. pygmaeus*).

Normal conjunctival bacterial flora was investigated in 10 raccoons (Procyon lotor). The most common isolate in raccoons was *Bacillus* spp. Other isolates included *Streptococcus* spp., *Staphylococcus* spp., non-hemolytic *Escherichia coli*, and *Enterococcus faecalis*. *Mycoplasma* culture was negative in all samples (Pinard et al. 2002). In another investigation using five Crab-eating raccoons (*P. cancrivorus*) no microorganisms were isolated from 10 eyes. In the remaining 10 eyes, *Staphylococcus* spp. was the most common microorganism isolated from conjunctival sac. *Shigella* spp. comprised the Gram-negative genera isolated (Spinelli et al. 2010).

Raccoons eat in the upright position, using the front paws and digits to wash, hold, and examine its food at close range. These behavioral and morphological features prompted structural and functional studies of the raccoon's accommodative capability. These investigations showed that the raccoon exhibits the greatest accommodative capability of any

Fig. 39.20 A 19-day-old red panda cub with ophthalmia neonatorum and a respiratory infection. Note the dried ocular discharge sealing the palpebral fissure of both eyes closed. Also, note the presence of nasal secretion. (Courtesy of Bret A. Moore)

non-primate terrestrial mammal so far studied. Parasympathetic stimulation of the meridional muscle fibers of the ciliary body results in forward lens movement induces accommodation of up to 19 D in the raccoon, which is 6 times more than in the dog (Rohen et al. 1989).

Similar to dogs (Wen et al. 1985), young raccoons exhibit a strong bluish reflection from their tapetal area (Fig. 39.22). The retina of the raccoon is of the holangiotic type. The meridian region of the eye, which lies in the horizontal plane and passes around the optic disc, had a markedly sparse capillary network. This horizontal sparse vascular band may correspond to a visual streak (Fig. 39.22). The sparse retinal capillary network in raccoons is extremely beneficial for photon capture, thereby allowing the raccoon to see well at night, as the retinal vessels restrict the inflow of photons toward the photoreceptors (Ninomiya et al. 2005).

Regarding developmental disorders of the eye, anophthalmos and microphthalmos were associated with nasomaxillary and central nervous system abnormalities in two unrelated raccoons (Render et al. 1983). In addition, another raccoon with a unilateral micro-ophthalmia has been documented (Hamir 2011). As for acquired ocular conditions, several systemic diseases may affect the raccoon eye. Mucus secretion was visible on the conjunctival in two juvenile raccoons (*Procyon lotor*) with disseminated histoplasmosis (*H. capsulatum*) (Clothier et al. 2014). Signs of canine distemper virus in raccoons may vary, but classically it starts with a mild green to yellow conjunctival discharge (due to a resulting *keratoconjunctivitis sicca*) (Fig. 39.23) from one or both eyes. Raccoons and striped skunks (*Mephitis mephitis*) have been investigated for rabies and canine distemper virus co-infections during a concurrent rabies and canine distemper outbreak in Ontario, Canada in 2015–2016. Several animals that were investigated presented ocular signs. Virus was detected using real-time PCR of conjunctival swabs in rabies positive raccoons (22/32) and skunks (7/34). Coinfections with both viruses should be considered, particularly in distemper endemic areas that are at risk of rabies incursion (Jardine et al. 2018).

Horner syndrome results from interruption of the oculosympathetic pathway. While Horner's Syndrome is a somewhat common neuro-ophthalmologic disorder in small

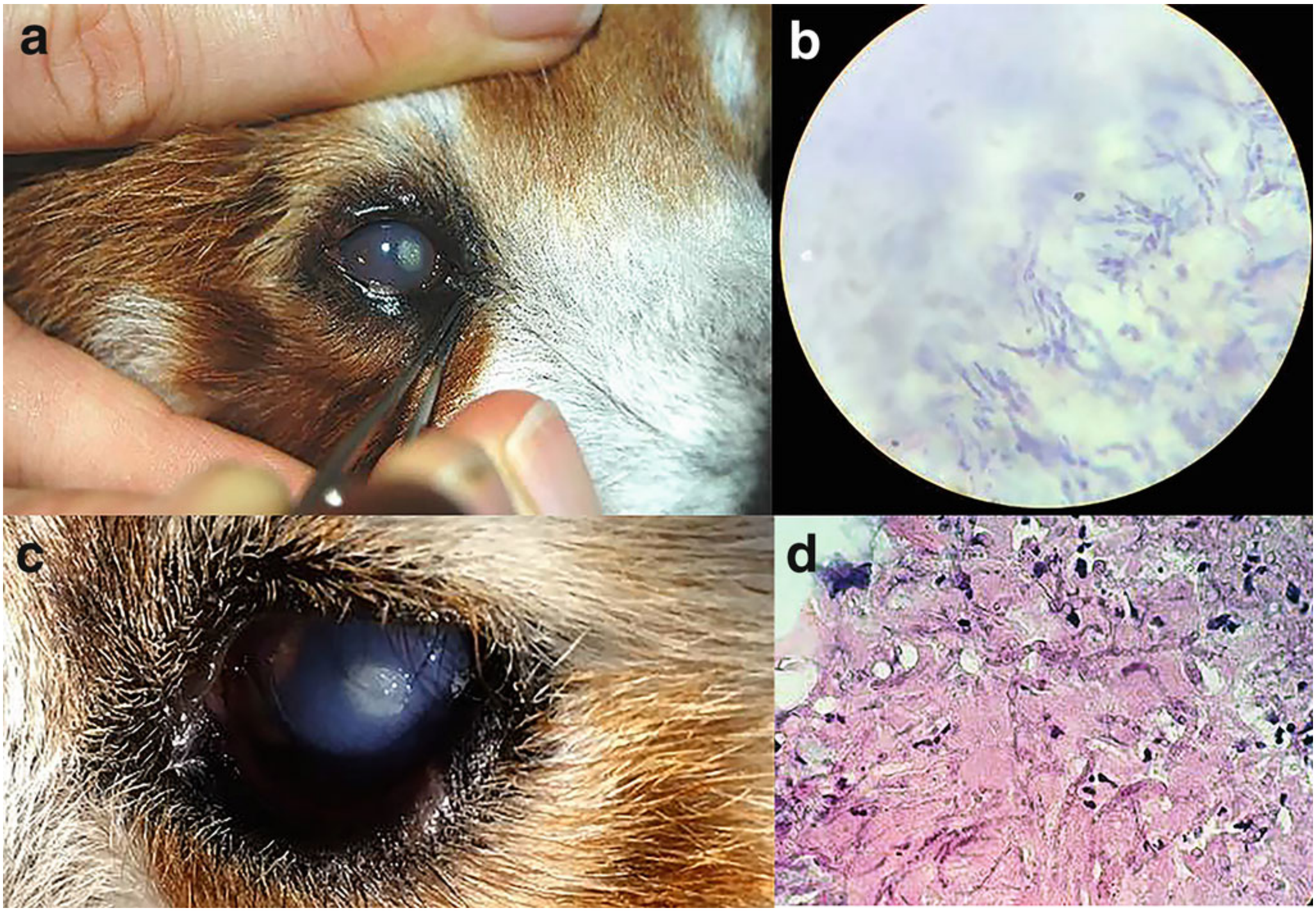

Fig. 39.21 Fungal keratitis in two captive red pandas. (**a**) Epithelial plaque and stromal abscessation in the right eye of a male red panda; (**b**) Cytology of affected corneal tissue from the same case, demonstrating filamentous fungal hyphae typical in appearance of *Aspergillus* spp. (**c**) Epithelial plaque and stromal abscessation in the left eye of a female red panda; (**d**) Histopathology of affected corneal tissue from the same case, demonstrating filamentous fungal hyphae, 100x magnification, oil immersion. From Volk HA, O'Reilly A, Bodley K, McCracken H. Keratomycosis in captive red pandas (*Ailurus fulgens*): 2 cases. Open Vet J. 2018;8(2):200–203 with permission

animal clinics, it is more complicated to detect in wild carnivores, yet diagnostic and therapeutic techniques applied e to domestic animals can be equally used as a reference for small carnivores of the Procyonidae family. A three-year-old male raccoon (*Procyon lotor*), castrated, from La Lajita Oasis Park Zoological Park (Spain) demonstrated a lack of appetite, state of mental depression, and mild dehydration. During physical examination, an abscess was observed in the left ventrolateral area of the neck as well as clinical signs compatible with Horner's Syndrome in the left eye, such as miosis, ptosis, enophthalmia, protrusion of the third eyelid (Fig. 39.24), anisocoria. A hypersensitivity test was performed by topical instillation of epinephrine 0.0001% on the left eye. Results suggested the presence of second-order Horner's Syndrome, probably caused by pressure from the abscess on the sympathetic innervation to the left eye. A radiologic study of the neck was carried out and blood samples and material from the abscess exudates were obtained. A culture of the exudates revealed the presence of *Escherichia coli*. Initial treatment was introduced according to indications resulting from the previously obtained antibiogram. Symptoms disappeared 6 days after the initial treatment (Nájera and Suarez 2012).

Coatis

Coatis, also are known as coatimundis, are members of the family Procyonidae in the genera *Nasua* and *Nasuella*. The two main (most common) species of coatis have are the South American ring-tailed coati (*Nasua nasua*), and the Central American white-nosed coati (*Nasua narica*). They are diurnal mammals native to South America, Central America, Mexico, and the southwestern United States. Coatis use

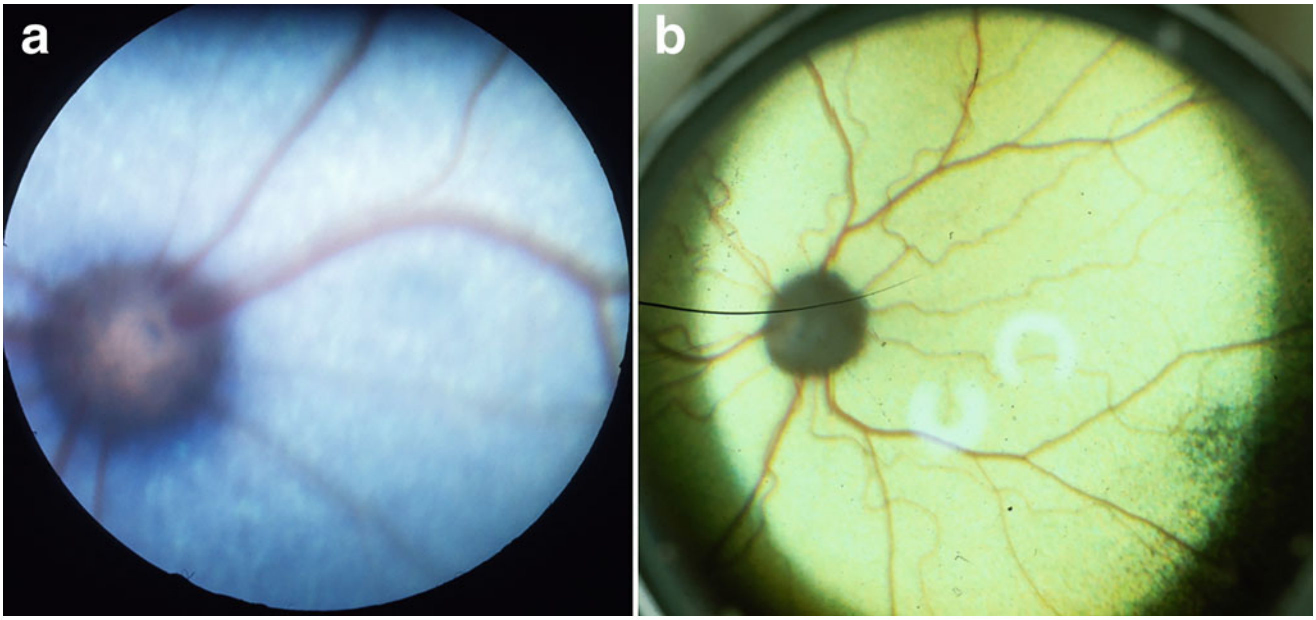

Fig. 39.22 Funduscopic images evidencing the holangiotic retina of raccoons (*Procyon lotor*) of different age groups. Note the bluish reflection from their tapetal area in a 6–8 week-old female raccoon (**a**). In this young adult raccoon, a yellowish reflection from their tapetal area is evident. Note the horizontal band of sparsely distributed retinal blood vessels corresponding to the raccoon retinal streak (*asterisks*) (**b**). (Courtesy of Christopher J. Murphy)

their long and flexible noses to push objects and rub parts of their body. The facial markings include white markings around the eyes and on the ears and snout. Kittens (coati babies) have their eyes closed at birth and usually only open them when they are about 10-days old. One interesting morphological features of the coati eye are the horizontally ovoid pupil (at rest), which when constricted becomes teardrop shaped, with the temporal edge being narrower than the

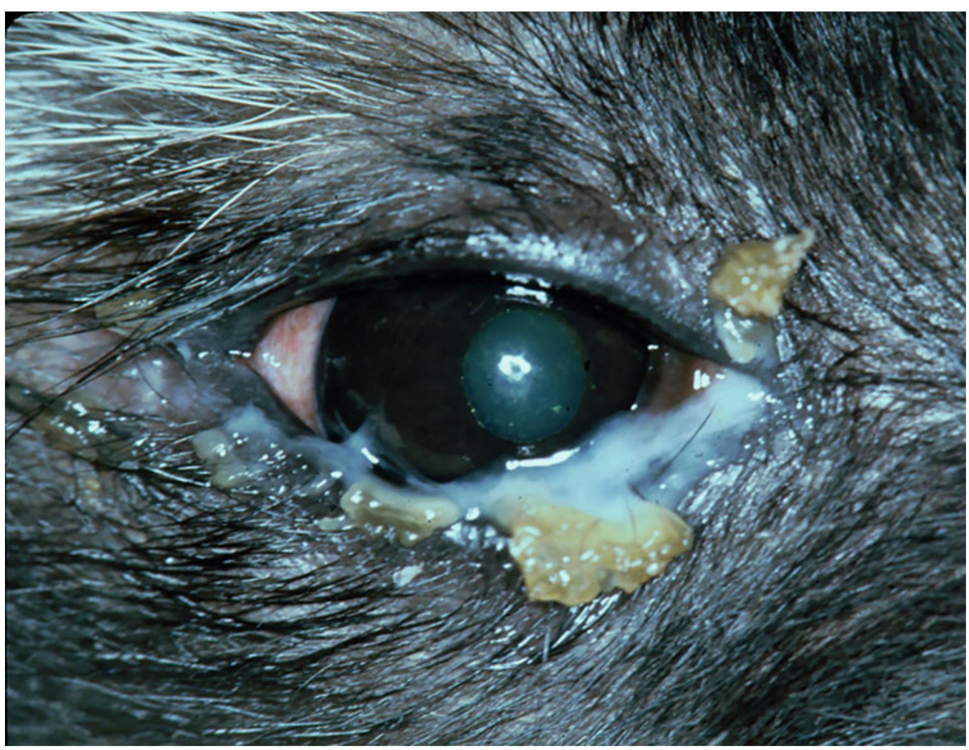

Fig. 39.23 A raccoon showing the classic ocular sign of canine distemper virus infection, a *green* to *yellow* conjunctival discharge. (Courtesy of Christopher J. Murphy)

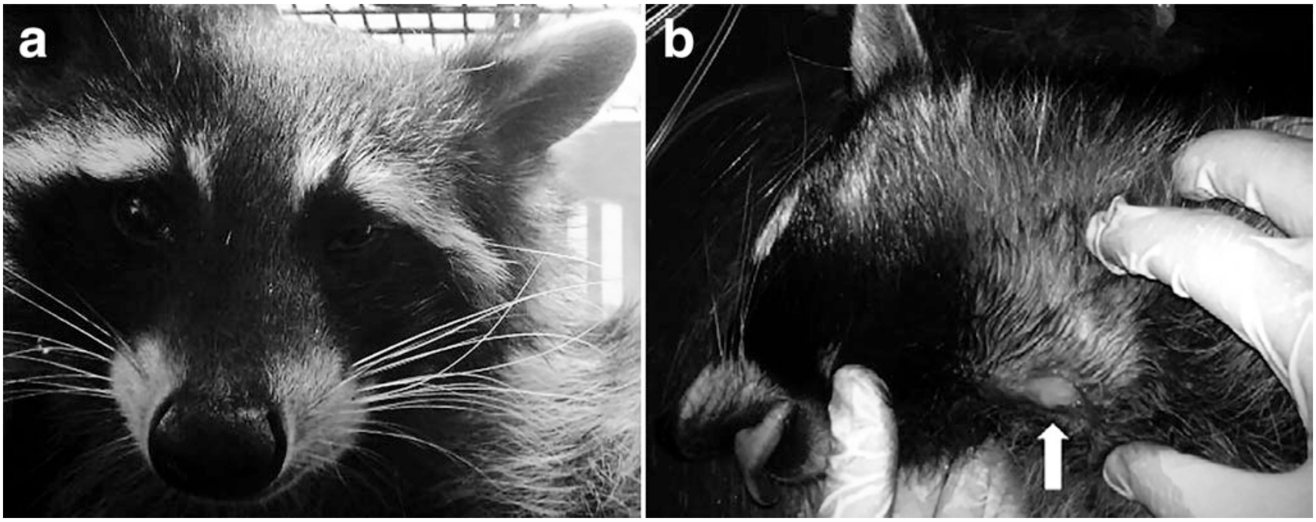

Fig. 39.24 Horner's syndrome in the left eye in a raccoon (*Procyon lotor*), associated with *Escherichia coli* neck abscess. (**a**) Note the ptosis, enophthalmia, slight protrusion of the third eyelid in the left eye. (**b**) Left ventrolateral view of the neck. Notice incision and exudate (*white arrow*). From: Nájera, F. and Suarez, A. 2012. "Horner's Syndrome associated with Escherichia coli Infection in a Raccoon (Procyon lotor)—A Case Report" Thai J Vet Med 42(3): 367–372. Figures 1 and 3. Used with permission

nasal and obliquely tilted ventrally (Fig. 39.25). The iris color in adults presents a dark brown color, while juveniles had a light brown. The fundus possesses a large tapetum lucidum, located dorsally. Its color varied with age, with adults having a green to yellow tapetum (Fig. 39.26) and juveniles being greenish-blue (Carvalho et al. 2021). The non-tapetal region is black. The optic disk is round, located in the tapetal region. No vascular ring was noted overlying the disk. The retina was holangiotic, with three to seven main veins emerging from the optic nerve, and several arterioles (Fig. 39.26).

A previous investigation with coatis describes the normal conjunctival microbiota. Results of this research showed that *Staphylococcus s*pp. was the most common microorganism isolated from conjunctival sac of coatis. *Escherichia coli* was isolated from the right eye of one coati that had no growth at contralateral eye. Nine eyes from coatis had no microorganisms isolated from the conjunctiva (Spinelli et al. 2010).

Severe inflammatory disease of the ciliary body (uveitis) associated with histopathologic detection of schizonts of the protozoan parasite *Sarcocystis neurona* in a White-nosed coati (*Nasua narica molaris*) has been reported (Dubey et al. 2017).

A coati was diagnosed with a unilateral dysfunction of the facial nerve-inducing exposure keratopathy (Fig. 39.27). On a survey performed by Carvalho et al. (2021), coatis aged 8–10 years of age commonly presented mild iris atrophy and nuclear sclerosis, with no predominance perceived among males or females (Fig. 39.28).

Kinkajou

Kinkajou, (*Potos flavus*), also called honey bear, is an unusual and elusive member of the Mustelidae family, notable by its long, prehensile tail that can curl around branches like a hand, short muzzle, and rounded ears. Native to the tropical rainforests of Central America and parts of South America. There are two possible theories to explain their other name "honey bears." The first one is because they like to lap up the honey from bees' nests with their long, narrow tongues. The second possibility refers to the typical golden color of the animal's soft fur (Crampton 2020). Kinkajous as part of the Musteoidea family, belonging to the family Procyonidae are classified as carnivores, mainly because of their skull structure and teeth. However, kinkajous in the wild are exclusively (or almost) vegetarian, feeding on fruit, leaves, flowers, and nectar. Kinkajous are important pollinators. As they travel from flower to flower to drink nectar, the flower's pollen sticks to their face and then smears off at the next flower. An interesting investigation on kinkajous diet described from analyses of feces and observations of habituated individuals showed the following results: Ripe fruit is the primary food comprising 90.6% of

Fig. 39.25 Note the horizontal ovoid pupil of a coati (*Nasua nasua*). Note that when constricted the pupil becomes teardrop shaped, with the temporal edge being narrower than the nasal and obliquely tilted ventrally. (Courtesy of Ana Carolina Rodarte)

feeding bouts and present in 99% of feces. Leaves and flowers made up <10% of the diet. No animal prey was eaten. Seventy-eight species of fruit from 29 families were detected. Moraceae was the main plant family in the diet and Ficus was the most important plant genus. Kinkajous is preferentially fed in large fruit patches. Selection indices were calculated for 37 fruit species. Compared with other large mammalian frugivores in central Panama the diet of kinkajous is most similar to the spider monkey (*Ateles geoffroyi*) (Kays 1999).

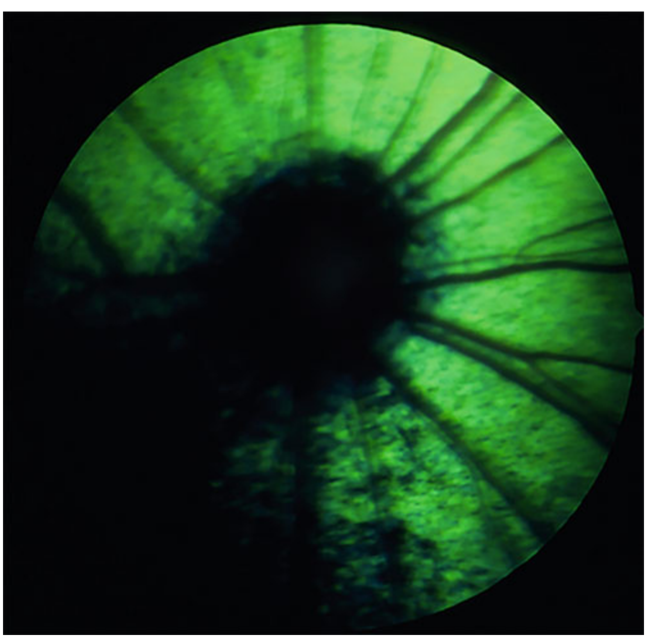

Fig. 39.26 Funduscopic image evidencing the holangiotic retina of the coati (*Nasua nasua*). Note the *bright green* tapetal shine and the retina richly vascularized with superficial blood vessels

Being arboreal and primarily active at night, the eyes of the kinkajous are adapted for nocturnal vision. In comparison to other members of the family Procyonidae, kinkajous possess a skull with a shorter rostrum. Their bony orbits and globe face more rostrally. Their eyes are comparatively bigger as well, with a wider corneal surface. Their vision has excellent brightness acuity and not so good color perception compared to coatis (Nasua nasua) (Chausseil 1992). This can be explained by the fact that in the family Procyonidae, the nocturnal raccoons (*Procyon lotor* and *P. cancrivorous*) and the nocturnal kinkajous (*Potos flavus*) lack S-cones while the diurnal coati (Nasua nasua) has L- and S-cones (Jacobs and Deegan 1992). There are one anecdotal report of a corneal ulcer diagnosed in one kinkajou.

Kinkajous are sometimes kept as exotic pets because they are generally playful, quiet and have little odor. Nevertheless, they can sometimes be aggressive. Kinkajous dislike sudden movements, loud noises, and being awake during the day. An agitated kinkajou may emit a loud noise and may attack,

Fig. 39.27 Photograph of a case of chronic epithelized (fluorescein-negative) exposure keratopathy in an adult coati (*Nasua nasua*) (Courtesy of Ana Carolina Rodarte)

usually clawing its victim and sometimes biting deeply. Kinkajous are captured for the exotic pet trade and hunted for their fur or meat. The fur is often used to make wallets or saddles. Despite these facts, the animal is not endangered at the moment (Crampton 2020). Kinkajou bites have a high risk of causing soft tissue infection in humans. There are reports of hand cellulitis and abscess after kinkajou bites (Hadvani and Dutta 2020). Pet kinkajous in the United States can be carriers (fecal–oral route) of the raccoon roundworm *Baylisascaris procyonis*, which is capable of causing severe morbidity and even death in humans, if the brain is infected (Kazacos 2001; Taira et al. 2018). A case of a novel rabies variant was discovered in a rabid wild kinkajou from Mato Grosso, Brazil, indicating a public health risk following exposure to either of the two animals (Dell'Armelina Rocha et al. 2020). Thus, kinkajous are not suitable pets for most people, because the species takes considerable resources to accommodate their needs (Wright and Edwards 2009).

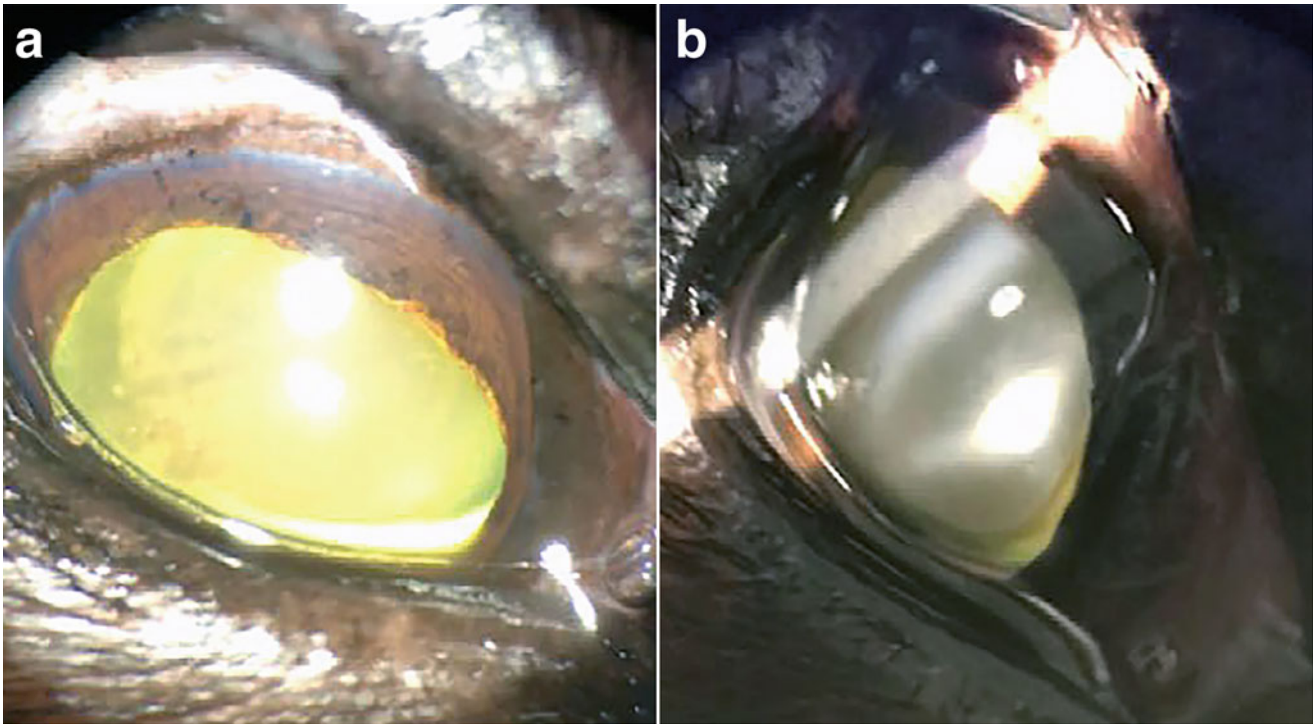

Fig. 39.28 Mild iris atrophy (**a**) and nuclear sclerosis in the left eye of an adult individual. (**b**) A better view of the mild nuclear sclerosis in the same animal depicted in (**a**) with the aid of a slit lamp. From: Carvalho CM, Rodarte-Almeida ACV, Moore BA, Borges BP, Machado MTS, Galera PD. Ocular examination findings and measurements of tear production and tonometry of ring-tailed coatis (Nasua nasua). Vet Ophthalmol. 2020. Epub ahead of print. PMID: 33547755. Used with permission

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