Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Chapter 20

Ophthalmology of Exotic Pets

Bradford J. Holmberg

Ocular anatomy of the vertebrate has been remarkably conserved throughout evolution. Structures universally present in these eyes are an outer fibrous tunic (cornea and sclera), middle vascular tunic or uvea (iris, ciliary body, choroid), inner neural tunic (retina), and internal optical media (aqueous humor, lens, vitreous). This basic pattern, particularly as it applies to mammals, is outlined in Chapter 1. Familiarity with general ocular anatomy and physiology is crucial to understanding the clinical signs and pathogenesis of ophthalmic disease. The objective of this chapter is to discuss differences in ocular anatomy and provide the general practitioner with information pertaining to the ophthalmic examination and diagnostic testing, common ophthalmic diseases, and their treatments in exotic species.

OPHTHALMIC EXAMINATION AND DIAGNOSTIC TESTING

Many of the exotic animal species are not accustomed to frequent handling or the restraint necessary to perform a thorough ophthalmic examination. Knowing the appropriate technique for proper restraint not only allows a better examination but also reduces overall stress on the animal. For example, the rear limbs and spine of a rabbit should always be adequately supported. When stressed, they may struggle, possibly resulting in hyperextension of the lumbosacral spine and vertebral fractures. During the examination of raptors, the practitioner must always be cognizant of the talons, because severe injury can occur if appropriate precautions are not taken.

The techniques used in the ophthalmic examination are no different whether one is examining an exotic species or a dog or cat. A guide to these techniques is outlined in Chapter 5. However, evaluation of the tear film, intraocular pressure (IOP), and fundus may be more difficult in exotic animals owing to their smaller globes.

The most common method of evaluating the tear film is through the quantification of aqueous tear production with a Schirmer tear test (see Chapter 9). The strips used for the test are 5 mm wide, making their use difficult in eyes in which palpebral fissure length is less than 1 cm. Historically, these strips have been cut lengthwise to decrease their width, allowing easier placement. However, because this practice is not standardized, there is large variability between results, making interpretation of values difficult.

A phenol red thread test is more appropriate for the smaller eyes of exotic animals. The test is performed similarly to the Schirmer tear test. The thread is placed in the lateral canthus for 15 seconds, and the millimeters of wetting are measured. Normal values for the Schirmer tear test and phenol red thread test for a number of species are shown in Table 20-1. Qualitative tear film deficiencies are currently diagnosed in canine and feline ophthalmology through the use of the tear film break-up time. This technique is not yet in common usage with exotic species.

The phenol red thread test is the preferred method to evaluate tear production in exotic pets.

IOP evaluation, or tonometry, can readily be performed in conscious exotic animals. Two types of tonometers are most frequently used to evaluate IOP, an applanation tonometer (Tono-Pen) and rebound tonometer (TonoVet). Published IOP values for a number of exotic animal species are shown in Table 20-2.

The small globe (short axial length) of many exotic animals increases the difficulty of critically examining the fundus. However, performing indirect ophthalmoscopy should be a standard part of the ophthalmic examination and is facilitated through pharmacologic mydriasis and use of a highly refractive indirect lens. Lenses of 30, 40, or 60 D are particularly useful. Pupillary dilation in mammals is achieved with 1% tropicamide, usually within 20 minutes and persists for 4 to 8 hours. The pupils of birds and reptiles will not dilate with anticholinergic agents owing to the presence of striated muscle fibers in both the pupillary sphincter and dilator muscles. Achieving mydriasis in these species is more difficult and may require intracameral infusion of curariform neuromuscular blocking agents. More recently, topical application of vecuronium bromide (1 drop twice at a 15-minute interval) with or without the addition of phenylephrine and atropine has been demonstrated to cause consistent mydriasis lasting 1.5 to 4 hours in birds. Other curariform neuromuscular blocking agents used topically have been associated with severe side effects, including paralysis of

Table 20-1 | **Normal Values for Tear Quantification Tests in Exotic Species**

SPECIES	SCHIRMER TEAR TEST RESULT	PHENOL RED THREAD TEST RESULT
Rabbit	5 ± 3 mm/min	24 ± 4 mm in 15 sec
Rat	8 ± 3 mm in 5 min	14 ± 3 mm in 2 min
Mice	3 ± 0.2 mm in 2 min*	3 ± 1 mm/min
Birds (Psittaciformes)	5 ± 3 mm/min	22 ± 4 mm in 15 sec

*Modified Schirmer tear test strip.

Table 20-2 | **Normal Intraocular Pressure Values for Exotic Species**

SPECIES	TONOMETRY VALUE (mm Hg)
Rabbit	13 ± 6
Ferret	23 ± 5
Mice	15 ± 5
Rat	15 ± 5
Birds (raptors)	20 ± 4
Owls	11 ± 4

muscles outside the eye, especially those of respiration. Caution should always be exercised in the use of these agents topically or intracamerally. Their use has not yet been evaluated in reptiles. Mydriasis may also be achieved with general anesthesia, although this method has its own inherent risks and complications.

Pharmacologic mydriasis is difficult to achieve in birds and reptiles due to the presence of striated iridal muscle fibers.

Other diagnostic tests, including fluorescein and rose bengal staining, exfoliative cytology, and microbial culture, are completed as they are in the more common domestic species; they are described in detail in Chapter 5.

RABBITS

Ophthalmic Anatomy

Like many prey species, rabbits have large, laterally placed eyes. The angle between their orbits is 150 to 175 degrees, allowing a visual field of almost 360 degrees. Their stereoptic vision is poor, with only 10 to 35 degrees of binocular overlap. The orbit contains a large venous sinus, extending from the orbital apex to the globe equator and draining posteriorly to the pterygoid and cavernous sinuses. This extensive vascular network within the orbit is a common cause of significant hemorrhage during enucleation.

The nasolacrimal apparatus of the rabbit is unique. Although rabbits only blink once every 5 to 6 minutes, their tear film remains stable and they rarely have exposure keratitis secondary to evaporation. Tear film stability is likely enhanced by the presence of four orbital glands: the lacrimal gland, an accessory lacrimal gland with retrobulbar, orbital, and infraorbital lobes, superficial gland of the third eyelid, and deep gland of the third eyelid (harderian gland). Retention of the lacrimal lake may be facilitated by the lack of a superior lacrimal puncta, which would result in a slower rate of tear clearance. The nasolacrimal duct follows a tortuous route through the lacrimal and maxillary bones and passes in close proximity to the apices of the molar and incisor teeth before emerging through the nasal mucosa. Owing to several sharp bends and associated duct narrowing, blockage of the duct and subsequent dacryocystitis is common.

The most remarkable anatomic difference of the rabbit eye from that of other species is its retinal vascular pattern. Lagomorphs are the only species with a merangiotic fundus, in which the retinal blood vessels radiate horizontally from the optic disc, running with the myelinated nerve fiber layer. The optic disc is situated in the superior fundus and thus requires that the examiner use an upward gaze to view the optic disc. An obvious central depression in the optic disc (physiologic cup) is apparent secondary to lack of a developed lamina cribrosa and extensive myelination of optic nerve axons at that point. This appearance can be challenging to distinguish from glaucomatous cupping of the optic nerve head.

Orbital Disease

Exophthalmos is the most prevalent clinical sign associated with orbital disease. In rabbits, retrobulbar abscesses are commonly the cause of exophthalmos (Figure 20-1). *Pasteurella multocida* has frequently been implicated as the cause for these abscesses, although confirmation through culture is rarely attained. Regardless of the specific pathogen responsible, it likely gains access to the orbit either through infected molar tooth roots or from hematogenous spread. Diagnosis is made through clinical signs and ocular ultrasonography. Successful treatment is difficult. The abscess cannot be drained through the oral cavity because of the rich vascular plexus lining the rabbit orbit as well as the extremely caseous nature of the contents. Many cases require exenteration and long-term medical therapy with a broad-spectrum antibiotic. True *Pasteurella*-induced abscesses may respond favorably to parenteral penicillin therapy at a dose of 60,000 IU/kg q24h for several weeks. However, the use of penicillins in rabbits warrants extreme caution because they can cause anaphylaxis or fatal enterocolitis due to alteration of the normal gastrointestinal flora. Even with aggressive surgical and medical therapy, many of these abscesses recur and at times necessitate euthanasia. Less common causes of exophthalmos in rabbits include parasitic cysts, orbital neoplasia, and metastatic thymoma.

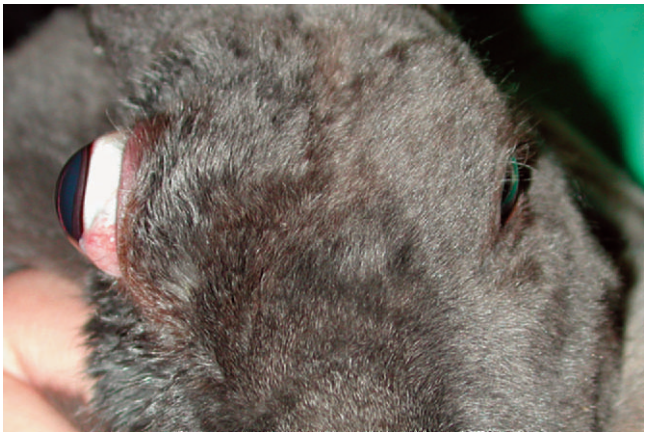

Figure 20-1. Marked exophthalmos of the right eye of a rabbit secondary to a large retrobulbar abscess. Culture of the abscess was negative for aerobic and anaerobic organisms.

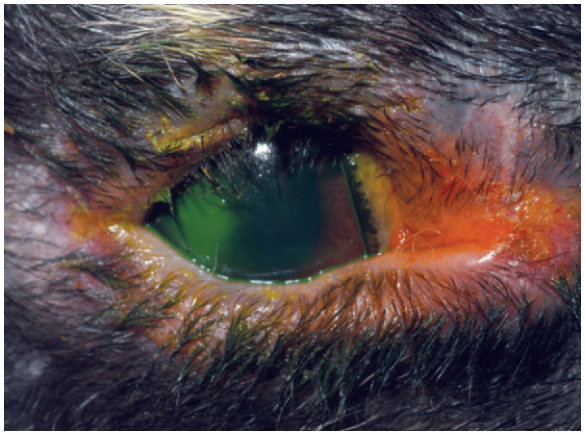

Figure 20-2. Entropion of the right upper eyelid of a rabbit with secondary ulcerative keratitis.

Figure 20-3. Marked blepharitis and severe mucopurulent ocular discharge in a rabbit with *Treponema cuniculi*.

The indiscriminate use of antibiotics with a gram positive spectrum in rabbits can result in severe, life-threatening complications.

Adnexal Disease

Adnexal disease is uncommon in rabbits, with entropion being the most commonly observed abnormality. Entropion may involve the upper and/or lower eyelids and may be primary or secondary. Primary (congenital) entropion has been described in the New Zealand white and French lop breeds. These breed predispositions suggest an inherited basis, but a mode of inheritance has not been determined. The lower eyelids are most commonly affected in New Zealand white rabbits, whereas the upper eyelids are affected in French lops. Clinical signs associated with primary entropion include epiphora, blepharospasm, conjunctival hyperemia, and, sometimes, ulcerative keratitis (Figure 20-2). Application of a topical anesthetic such as 1% proparacaine will facilitate ophthalmic examination by alleviating surface ocular pain. It will also remove any spastic component to the entropion, allowing appropriate surgical planning. Correction of entropion with a modified Hotz-Celsus procedure allows restoration of normal anatomic conformation, thereby preventing further ocular irritation.

Entropion may occur from cicatrix formation secondary to chronic blepharitis or blepharoconjunctivitis. Before any attempt at surgical correction, the underlying cause must be identified and treated. Otherwise entropion will likely recur. Cicatricial entropion is corrected using a Y-to-V blepharoplasty, with care taken to completely excise the offending fibrotic tissue during the procedure. Infectious blepharitis may result from exposure to *Treponema cuniculi*, or rabbit syphilis (Figure 20-3). *T. cuniculi* is a spirochete bacillus transmitted by infected dams. The most commonly affected areas are the vulva, prepuce, lips, nares, and anus. Clinical signs include thickening, crusting, and, possibly, ulceration of the eyelid. Diagnosis is confirmed through identification of spirochetes in biopsy or skin scraping samples. Darkfield microscopy enhances visualization of the organism. Three doses of parenteral benzathine penicillin G or procaine penicillin G at a dose of 42,000 IU/kg at 7-day intervals is the treatment of choice. Careful monitoring of the patient for potentially fatal enterocolitis is necessary. Blepharitis may also be caused by self-induced trauma or maceration due to ocular discharge secondary to dacryocystitis, conjunctivitis, or keratitis (discussed later).

Neoplasia of the eyelids is rarely reported in the rabbit. The most common tumors of the eyelid are squamous cell carcinoma, fibrosarcoma, and melanoma. Squamous cell carcinoma must be differentiated from treponemal blepharoconjunctivitis, because both can have similar clinical presentations. Diagnosis is made through biopsy, preferably excisional biopsy, which may be curative in cases of squamous cell carcinoma. If diffuse disease prevents complete excision, adjunctive therapy with β-irradiation or cryotherapy may be used. If these modalities are not available, referral or enucleation is recommended. Fibrosarcoma manifesting in the eyelid may represent extension from the orbit. Careful examination, including globe retropulsion as well as advanced imaging using computed tomography (CT) or magnetic resonance imaging, may aid in distinguishing the extent of tumor involvement. Orbital involvement carries a guarded prognosis. Exenteration may be palliative and may increase survival time. Melanomas of the eyelid tend to be benign although locally invasive. Surgical excision is curative.

Conjunctival Disease

Conjunctivitis may be a primary clinical sign but is frequently associated with blepharitis or keratitis. Noninfectious causes of conjunctivitis include keratoconjunctivitis sicca, trauma (self-induced or due to foreign bodies such as straw, dust, seed husks), and environmental allergens. Keratoconjunctivitis sicca is uncommon, is diagnosed with the aid of a Schirmer tear test with accompanying clinical signs, and is frequently the result of chronic conjunctivitis. Treatment consists of artificial tear replacement therapy.

Bacteria and viruses are commonly present in infectious conjunctivitis; however, fungi are rarely encountered. Offending bacteria may represent overgrowth of the normal conjunctival flora and include *Staphylococcus aureus*, *P. multocida*, *Haemophilus* spp., *Pseudomonas* spp., and *Chlamydia* spp. Treatment should be based on results of culture and sensitivity testing but frequently includes topical chloramphenicol or ciprofloxacin used long term. Relapses are common, and the addition of systemic antimicrobial agents may be necessary.

Viral causes of ophthalmic disease are relatively uncommon in domestic rabbits in the United States. Myxoma virus is a member of the Poxviridae family and is endemic in the western United States (especially among brush rabbits in California), Europe, and Australia. The virus is transmitted by an arthropod vector, including both mosquitoes and fleas. Clinical signs are blepharoconjunctivitis with a thick mucopurulent discharge, blepharedema, and edema and nodule formation on the ears, head, body, and limbs. Myxoma virus was formally thought to have 100% mortality, but more recent data suggest that the prognosis varies according to the strain of the virus and species/breed of rabbit. Diagnosis is obtained from clinical signs, gross pathology findings, and polymerase chain reaction (PCR) analysis of tissue extracts. Treatment is supportive only.

Rabbit fibroma virus has also been responsible for the formation of flat, subcutaneous tumors of the periocular skin. Similar to myxoma virus, it is also a member of the Poxviridae family and is transmitted by an arthropod vector. Unlike with myxoma virus, lesions resolve spontaneously and treatment is usually not necessary. A predisposition of fibroma virus for cottontail rabbits is reported. Differentiation of this virus from myxoma virus is important because the prognoses for survival are significantly different.

Formation of a conjunctival membrane over the corneal surface is a condition unique to rabbits. This condition has been labeled pseudopterygium, corneal occlusion syndrome, conjunctival centripetalization, and epicorneal membrane (Figure 20-4). Progressive ingrowth of the bulbar conjunctiva occurs symmetrically and centripetally. The conjunctiva does not adhere to the corneal surface, separating this condition from true pterygium described in humans. The disease may be unilateral or bilateral. The cause has not been determined, although a collagen dysplasia has been proposed. Surgical correction is completed through a modified Arlt procedure. The conjunctival tissue is partially trimmed by sharp dissection, divided in half along the horizontal axis, and the leading edge is sutured to the conjunctival fornix. Because of the likelihood that this disease is immune mediated, application of cyclosporine, mitomycin C, or a steroid may decrease recurrence. However, topical administration of these agents may result in systemic immunosuppression and therefore they must be used with caution.

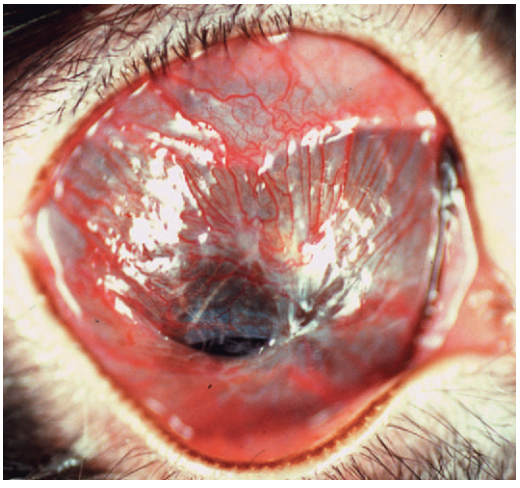

Figure 20-4. Pseudopterygium in a rabbit. The conjunctiva has grown centripetally over the corneal surface. Only a small area of cornea is noticeable (black ovoid area).

Nasolacrimal Disease

The tortuous path of the rabbit nasolacrimal duct predisposes it to recurrent dacryocystitis. Primary duct occlusion may occur with oil droplets or inspissated purulent material. Dental disease or osseous changes to the maxillary bone secondary to nutritional hyperparathyroidism may also lead to the development of duct obstruction. Of these, dental disease is alleged to be the most common cause. Malocclusion of the molars and premolars and, less frequently, the incisors results in retropulsion of the tooth and impingement on the nasolacrimal duct. Secondary infection ensues, and a wide range of organisms has been cultured, including *Neisseria, Moraxella, Bordetella, Streptococcus viridans, Oligella urethralis, Pasteurella,* and *Pseudomonas*. Clinical signs include epiphora, usually in conjunction with mucopurulent discharge. Secondary conjunctivitis may also be present. Dacryocystitis can be differentiated from primary conjunctivitis by digital pressure on the lacrimal sac. With dacryocystitis, a mucopurulent exudate can usually be expressed from the lacrimal puncta. Diagnosis is made on the basis of clinical signs and a negative fluorescein dye passage test result. A CT scan or plain radiograph of the head, sometimes augmented by dacryocystorhinography, may aid in differentiating the underlying cause and location of duct obstruction. Treatment is first aimed at correcting the underlying abnormality, especially correction of any dental disease (occlusal adjustment). The duct is then flushed with sterile saline through a 23-gauge lacrimal cannula. After flushing with saline, dilute povidone-iodine solution (1:50) is flushed through the duct. Repeated flushings may be necessary to maintain patency of the duct. If the duct cannot be flushed, long-term systemic antibiotic therapy (enrofloxacin 5 mg/kg/day) may be necessary to control infection. Recurrences are common.

Dacryocystitis is usually secondary to dental disease in rabbits.

As in dogs, prolapse of the gland of the third eyelid may occur in rabbits. This is uncommon and usually involves the harderian gland. Chronic conjunctivitis commonly persists without treatment. Surgical therapy is curative and involves performing a modified Morgan-pocket technique. The gland should not be surgically excised because there is significant vascularization of the gland, so severe hemorrhage may occur.

Corneal Disease

The large, prominent globes and decreased blink rate of rabbits may predispose them to corneal disease. Corneal ulceration is common; it may be associated with trauma, exposure after anesthesia, distichiasis, entropion, and trichiasis and may occur secondary to blepharoconjunctivitis or dacryocystitis. Thorough examination will aid in differentiating the underlying cause. If no conformational abnormality is noted, trauma can be assumed. Diagnosis is facilitated by the use of fluorescein stain as in other species. Uncomplicated defects are treated symptomatically with a broad-spectrum topical antibiotic, such as chloramphenicol, several times daily. Ulcers that do not heal, have significant stromal loss, or are infected are deemed "complicated" and require more intensive therapy. Nonhealing or indolent corneal ulcers are common and should be treated like those in dogs. Aggressive corneal débridement with a

cotton-tipped applicator after topical anesthesia is recommended. A grid or multiple superficial punctate keratotomy may also be necessary to promote healing. Cytology and culture and sensitivity testing of infected corneal ulcers are recommended so that appropriate antibiotic therapy can be initiated. When there is significant stromal loss or a descemetocele is present, referral to an ophthalmologist is warranted. Placement of a conjunctival pedicle graft is the treatment of choice, although this procedure is more difficult in rabbits owing to their notably thin cornea (0.36 mm) compared with dogs (0.56 mm). After surgery, antimicrobial therapy is initiated on the basis of cytology and culture results. Reflex uveitis secondary to keratitis likely occurs in rabbits as it does in dogs, and application of atropine may help alleviate ciliary spasm associated with uveitis through cycloplegia. However, the presence of atropinase in the rabbit uvea may prevent its effectiveness. Because atropinase is not universally present and not all rabbits are immune to atropine's effects, its application is recommended. During treatment of corneal disease in rabbits, ophthalmic solutions or suspensions are preferred to ointments because of their normal grooming behaviors.

White corneal opacities are occasionally observed and may represent either mineral or lipid. Corneal dystrophy with subepithelial mineral deposition has been described as an inherited trait in American Dutch belted rabbits. Treatment is not usually necessary because the lesions do not cause visual deficits or keratitis. Corneal lipidosis occurs secondary to high cholesterol diets in most rabbit species. A hereditary hyperlipidemia has been described in the Watanabe rabbit. Lipid accumulates first at the limbus and then may proceed axially, resulting in either a subtle or marked opacity with obvious keratitis. Depending on the degree of keratitis and size of the plaque, conservative (dietary) therapy may be sufficient. However, if the plaque is large and causing visual deficits, a superficial keratectomy is recommended. Definitive diagnosis is obtained through histopathologic analysis of keratectomy specimens with appropriate stains such as oil red O.

Cataract

Cataracts may occur spontaneously or may be secondary to uveitis in rabbits. Some spontaneous cataracts (Figure 20-5) are suspected to be inherited in nature, although no genetic evidence is available because of the low incidence. Evaluation of laboratory New Zealand white rabbits revealed a 4% prevalence of spontaneous cataracts with no difference between males and females. Treatment is necessary only if secondary lens-induced uveitis or visual deficits are present. Removal of the lens via phacoemulsification is the treatment of choice. The procedure is similar to that performed in dogs, although the surgeon must take care upon entering the anterior chamber, because it is shallow and iris prolapse through the incision is more likely. Additionally, meticulous irrigation/aspiration of the peripheral lens cortex is necessary owing to the greater likelihood of lens fiber regrowth.

Uveitis was considered the most common cause of cataracts in rabbits. Rabbits were usually presented with a discrete, white, raised abscess within the iris overlying a focal cataract. Aqueous flare and hypotony were also present. Septicemia secondary to *Pasteurella* or *Staphylococcus* spp. was implicated as the cause of uveitis. Diagnosis was based solely on ophthalmic clinical signs, although many animals also had systemic disease consistent with septicemia. Diagnostic samples for culture and cytology via aqueocentesis were obtained infrequently due to the relative invasiveness of this procedure. When performed, organisms were rarely cultured or observed on cytologic preparations. Further evaluation of these iridal abscesses has revealed pyogranulomatous inflammation associated with lens capsule rupture (phacoclastic uveitis). Therefore the uveitis may have not been the inciting cause but the result of cataract formation with subsequent lens capsule rupture.

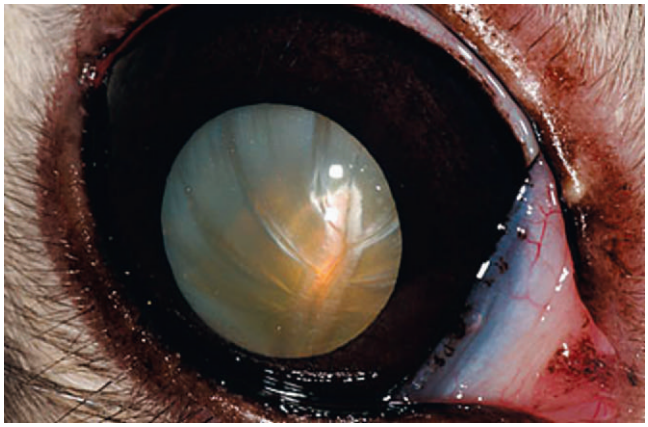

Figure 20-5. A complete, spontaneous cataract in a rabbit.

Intralenticular organisms have been identified in approximately 75% of rabbits with cataract formation with secondary phacoclastic uveitis. These organisms were 1 to 6 µm in size and consistent with the obligate intracellular protozoa, *Encephalitozoon cuniculi*. Rabbits are infected with *E. cuniculi* after ingestion of food contaminated with urine. Nonocular signs include neurologic disease (head tilt, torticollis, seizures, ataxia, paralysis) and renal disease. Lens infection occurs in utero owing to vertical transmission from an infected dam. Dwarf and young rabbits are predisposed. Clinical signs are usually unilateral and include spontaneous lens capsule rupture with resultant phacoclastic uveitis (including aqueous flare, hypopyon, and hypotony), iridal granuloma formation, and cataract formation (Figures 20-6 and 20-7). Diagnosis is based on clinical signs along with supportive results from serology (indirect fluorescent antibody test, enzyme-linked immunosorbent assay) or PCR analysis of lens tissue. Serology is quite

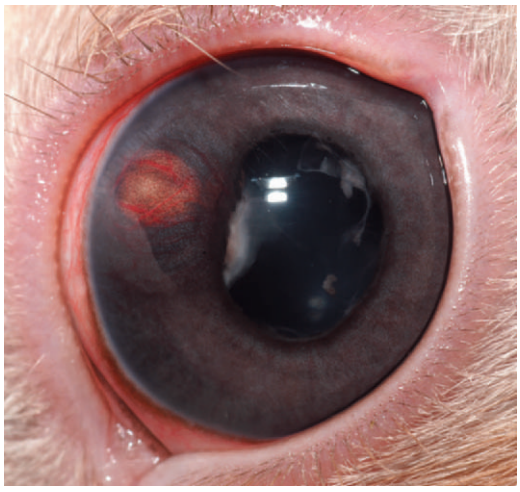

Figure 20-6. Focal lens capsule rupture, cataract, and iridal granuloma formation in a dwarf rabbit with *Encephalitozoon cuniculi*.

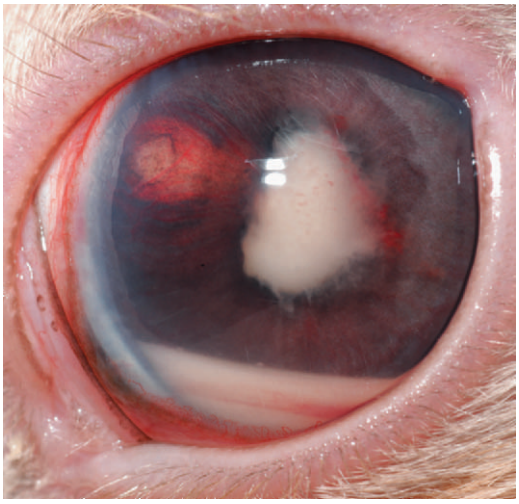

Figure 20-7. Same rabbit as in Figure 20-6, after 2 weeks without therapy. Phacoclastic uveitis is present as evidenced by lens capsule rupture, cataract formation, hyphema, and hypopyon.

sensitive, as rabbits mount a humoral response within 2 weeks, and in one study 100% of rabbits with ocular signs were seropositive.

Surgical therapy is recommended for *E. cuniculi*–induced lens capsule rupture and, when successful, is curative. The lens is removed by phacoemulsification and the iridal granuloma can be aspirated by automated irrigation/aspiration. Medical therapy alone may slow progression of the uveitis but rarely clears the infection. Medical treatment involves frequent use of topical antiinflammatory agents. Because of their relative lack of potential side effects, nonsteroidal antiinflammatory drugs (NSAIDs), such as flurbiprofen and diclofenac, are preferred over topical steroids. The antiparasitic agent albendazole has demonstrated efficacy in vitro, but its in vivo activity seems poor. The recommended dose of albendazole is 20 to 30 mg/kg once daily for 3 to 10 days, and that for fenbendazole is 20 mg/kg once daily for 28 days. However, they must be used with extreme caution because severe side effects, including death, have occurred with their use.

Encephalitozoon cuniculi is the most common cause of phacoclastic uveitis in rabbits.

Glaucoma

An inherited glaucoma is recognized in New Zealand white rabbits. Rabbits homozygous for the *bu* gene experience an increase in IOP at 1 to 3 months of age. Buphthalmos and blindness ensue, and over time the IOP returns to normal secondary to ciliary body degeneration. Histopathology demonstrates classic pectinate ligament dysplasia as the cause of glaucoma. Medical therapy is ineffective, and surgical intervention (cyclophotocoagulation, cyclocryoablation, gonioimplants) has not been reported. The *bu* gene is semilethal, and affected rabbits should not be bred. Primary glaucoma not associated with the *bu* gene is uncommon.

Most cases of glaucoma are secondary to lens-induced uveitis due to *E. cuniculi* infection. These cases may respond to topical carbonic anhydrase inhibitors applied every 8 hours (see Chapter 12). If satisfactory control of IOP is not accomplished, a topical β-blocker, such as 0.25% timolol, can be added to the treatment protocol. Whenever using topical medications the animal must be carefully monitored for systemic side effects.

FERRETS

Ophthalmic Anatomy

Even though ferrets are carnivorous, their eyes have aspects consistent with eyes of both predator and prey species. The globes are laterally placed in a deep, open orbit approximately 32 degrees off midline, providing a visual field of about 270 degrees. Stereopsis is limited to approximately 40 degrees. The pupil is horizontally ovoid, decreasing light exposure and bleaching of the rod photopigment during daylight hours. Nocturnal vision is improved by the rod-dominated retina and a tapetum rich in zinc and cysteine, similar to that in the dog. Ferrets have a holangiotic retinal vascular pattern, and the optic disc is variably myelinated.

Orbital Disease

Like rabbits and rodents, ferrets have a well-developed retrobulbar venous plexus. This has been used as a blood collection site, with a technique similar to that described in rodents. However, this technique should not be used, especially in pet ferrets, owing to the potential for severe ocular complications, including globe rupture, corneal ulceration, hematoma formation, and exophthalmos. Exophthalmos may also be caused by retrobulbar neoplasia or zygomatic salivary gland mucocele formation. Lymphoma is the third most common neoplasia in pet ferrets as well as the most common retrobulbar neoplasia in this species. Exophthalmos is often the initial clinical sign of lymphoma. Complete blood count alterations and mediastinal masses may also be present, necessitating a thorough systemic evaluation. Because clinical progression can be rapid, early diagnosis and treatment with chemotherapy offer the best chance for remission.

The ferret's zygomatic salivary gland is located ventral and posterior to the globe. Trauma to the head has been implicated as the cause of mucocele formation. Diagnosis is based on findings of ocular ultrasonography and cytologic evaluations of fine-needle aspirates. Cytology may show mucinous debris with few red blood cells, inflammatory cells, and epithelial cells. Treatment is surgical removal via orbitotomy, which is curative.

Conjunctival Disease

Infectious conjunctivitis in ferrets is usually a manifestation of systemic disease. Commonly incriminated causes are canine distemper virus, human influenza virus, salmonellosis, and mycobacteriosis.

Canine distemper virus is a RNA virus of the morbillivirus genus. Ferrets are infected by direct contact with saliva, feces, or urine. Infection is now uncommon because of vaccination, which is recommended because mortality rates approach 100%. Clinical signs begin 7 to 10 days after infection with the onset of moderate conjunctivitis and mucopurulent ocular discharge. Additional ocular signs include blepharitis, keratoconjunctivitis sicca, ulcerative keratitis, and photophobia. With disease progression, anorexia, pyrexia, and hyperkeratosis of the foot pads occur. Death ensues within 12 to 35 days after infection,

depending on the strain (canine versus ferret). Diagnosis is obtained in an animal with suspicious clinical signs by means of the indirect fluorescent antibody test on conjunctival scrapings. Cytologic examination of conjunctival scrapings may also show intracytoplasmic eosinophilic inclusions similar to those seen in the dog.

Human influenza virus types A and B have been responsible for mild conjunctivitis in ferrets. Infection occurs via aerosolized droplets from the nasal mucosa. Other clinical signs are anorexia, sneezing, pyrexia, and serous nasal discharge. Treatment is merely supportive because most adults recover. Neonates may succumb to a secondary bacterial infection, requiring systemic antibiotics. The clinical signs may mimic those of canine distemper virus infection, and differentiation of these two etiologies is important because the prognoses for survival differ significantly.

More substantial conjunctivitis has been noted with septicemia secondary to *Mycobacterium* and *Salmonella*. Disseminated mycobacteriosis caused by *Mycobacterium genavense* may cause generalized conjunctivitis or a focal lesion. Aggressive therapy with oral rifampicin, clofazimine, and clarithromycin along with topical chloramphenicol was curative. Diagnosis is obtained through PCR analysis of conjunctival biopsy samples. Systemic salmonellosis may result in conjunctivitis and is commonly accompanied by hemorrhagic diarrhea and fever.

Conjunctivitis in ferrets may be an extension of systemic disease and warrants thorough evaluation.

Cataract

Spontaneous cataracts are considered the most common ocular abnormality in ferrets. When their eyes were evaluated by slit-lamp biomicroscopy, approximately 47% of 1-year-old laboratory ferrets in one study had some form of cataract. Cataracts ranged from incipient to hypermature, and progression was common. The cause is not known, although genetic and nutritional (hypovitaminosis A) causes have been postulated. An autosomal dominant cataract has been described and is associated with microphthalmia, thickened irides, and progressive retinal degeneration. Surgical removal of spontaneous cataracts via phacoemulsification in ferrets with normal-size globes is similar to that in other species. The normal ferret is moderately hyperopic (approximately 7 D), and therefore one can assume that the aphakic eye is severely hyperopic and visual acuity is greatly impaired. However, aphakic ferrets appear to behave as if sighted but may be using olfactory cues and vibrations from the vibrissae to navigate.

MICE AND RATS

Ophthalmic Anatomy

The rodent eye is similar in structure to the rabbit eye. Posterior to the globe, an orbital venous plexus is present in rats, and an orbital venous sinus is present in mice. As in the rabbit, this collection of vessels and blood behind the globe can become a source of significant hemorrhage during enucleation. This area has been used for blood collection in laboratory animals but should not be performed in pet mice and rats owing to the potential for severe, globe-threatening complications, including exophthalmos, retinal detachment, globe puncture, and necrosis of the harderian gland. Three lacrimal glands are also located posterior to the globe: the intraorbital, extraorbital, and harderian glands. The extraorbital gland is commonly mistaken for a mass because it is located at the base of the masseter muscle. The harderian gland is located within the orbit adjacent to the third eyelid. This gland not only is important in production of the tear film but also may have a role in social interactions through the production of pheromones. Melatonin, a hormone involved in regulating circadian rhythms, is also produced by the harderian gland and has been suggested to be involved in extraretinal photoreception much like the pineal gland. However, because diurnal fluctuations in harderian gland melatonin concentration and secretion are not always present, the purpose of this tear component is not known.

The lens of mice and rats is large and spherical, resulting in a narrow anterior chamber. The size and shape of the lens suggest that the rat eye is hyperopic. However, retinoscopy of rat eyes has revealed a large variation in refractive error, ranging from near emmetropia (–0.1 D) to extreme hyperopia (+19 D). The large lens also distorts the image of the fundus obtained with indirect ophthalmoscopy, making the retina *appear* detached. The retina is holangiotic with blood vessels radiating from the optic disc. Because of the rat's nocturnal lifestyle, it is not surprising that its retina is dominated by rod photoreceptors. In young rats it is common to see persistent hyaloid vasculature extending from the optic disc toward the posterior pole of the lens. The patency of this vessel usually subsides over time but can occasionally cause transient vitreous hemorrhage. Common diseases of the rat and mouse eye involve the nasolacrimal system, cornea, lens, and fundus.

Nasolacrimal Disease

Chromodacryorrhea is the excessive production of "red tears." The red discoloration of the tears should not be confused with blood. Porphyrins in the tears secreted by the harderian gland are responsible for the reddish brown color seen with this condition (Figure 20-8). The harderian gland is innervated by the parasympathetic nervous system, and any increase in parasympathetic drive can result in chromodacryorrhea. Usually clinical signs are associated with nutritional deficiencies, chronic physiologic stress, chronic light exposure, or dacryoadenitis. Evidence of chromodacryorrhea should prompt the clinician to evaluate the animal for systemic disease.

Dacryoadenitis in rats is commonly secondary to sialodacryoadenitis virus (SDAV) or mycoplasmosis. SDAV is a coronavirus that is readily transmitted between rats by aerosol,

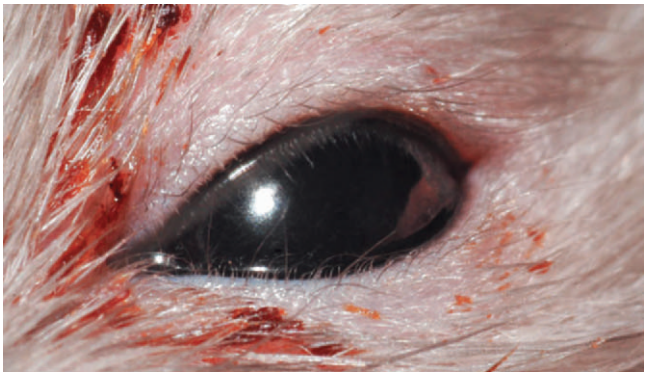

Figure 20-8. Chromodacryorrhea in a rat with sialodacryoadenitis virus.

direct contact, or fomite transmission. Early signs include blepharospasm, photophobia, and epiphora, but the most obvious finding is intermandibular swelling due to inflammation of the submandibular salivary glands. Chromodacryorrhea and exophthalmos due to inflammation of the harderian gland may occur over several days. Chronic cases may cause keratitis, ulcerative keratitis, keratoconjunctivitis, uveitis, hyphema, multifocal retinal degeneration, and secondary cataract or glaucoma formation. The virus is usually self-limiting, and the harderian gland may recover, depending on the degree of ductal squamous metaplasia and periacinar fibrosis. Mycoplasmosis is a primary cause of conjunctivitis in rats and may also cause dacryoadenitis. Other bacteria, including *Pseudomonas, Salmonella, Streptobacillus,* and *Corynebacterium,* have been implicated in conjunctivitis in rats. Treatment is based on culture and sensitivity results. Chloramphenicol (0.25 mg/mL) or oxytetracycline in the drinking water (3.5 mg/day) may be efficacious, depending on the offending agent.

Exophthalmos is not commonly observed in rats and mice. Most cases are secondary to inflammation of the harderian gland or iatrogenic trauma to orbital structures during retrobulbar blood collection. Aged rats may be presented with unilateral exophthalmos without signs of dacryoadenitis. In these cases retrobulbar neoplasia secondary to adenocarcinoma, carcinoma, and poorly differentiated sarcomas may be present.

Corneal Disease

Multifocal, punctate subepithelial white opacities are commonly observed in the interpalpebral fissure of both rat and mice corneas. Approximately 6% to 15% of rats have corneal dystrophy, with Sprague-Dawley, Wistar, and Fischer 344 breeds predisposed. The opacities are usually present shortly after birth and do not tend to progress. Corneal degeneration has been reported in mice, most likely secondary to environmental ammonia concentrations. Mice kept in clean cages or lower in racks had a much lower incidence of corneal degeneration than those kept in cages cleaned less frequently or in higher racks. Unlike dystrophy, corneal degeneration is not inherited and may progress, as evidenced by more severe corneal opacification in aged mice. Treatment is not necessary for dystrophy. Degeneration is best treated by prevention, keeping environments clean and ammonia concentrations low.

Cataract

Spontaneous cataracts occur in about 10% of rats and mice, with mice more frequently affected. These cataracts are usually focal and do not significantly interfere with vision. An interesting phenomenon has been observed in anesthetized mice. After approximately 10 minutes of anesthesia, anterior subcapsular cataracts develop and become denser over time. After anesthetic recovery, the cataracts gradually resolve over 24 hours. Theories for the formation of the transient cataracts included anesthetic type and changes in anterior chamber temperature. However, it has been demonstrated that these cataracts are secondary to tear film evaporation. With evaporation of the tear film, the aqueous osmolarity increases and fluid is lost from the anterior lens, resulting in a cataract. Prevention of these cataracts is easily accomplished by either taping the eyelids closed or applying a lubricating artificial tear preparation at the start of anesthesia.

Transient, anesthesia-induced cataracts in mice and rats are secondary to tear film evaporation.

Retinal Disease

Two retinal diseases in mice and rats warrant discussion, primary and secondary retinal degeneration. Primary or heritable retinal degeneration has been described in the Royal College of Surgeons rat. Degeneration occurs within the first 2 weeks of life secondary to impaired phagocytosis of rod outer segments by the retinal pigmented epithelium. This rat strain has been extensively used as a model for retinitis pigmentosa in humans. The most common form of secondary retinal degeneration is phototoxic retinopathy. There are two forms, determined by whether animals are exposed to extremely bright light for short durations or to low-intensity light for long periods. The first type results in damage to both the photoreceptors and retinal pigmented epithelium, and the second type primarily affects the photoreceptors. Factors associated with occurrence of phototoxic retinopathy include location of cage relative to the light source (usually animals in top cages are more severely affected), type of cage top (clear plastic versus metal), duration and intensity of light, age of the animal, and extent of ocular melanosis. Albino mice and rats are more sensitive because they lack protective melanin in the retinal pigmented epithelium. Phototoxic retinopathy most commonly occurs because of a light timer malfunction or human error.

RAPTORS AND PET BIRDS

Ophthalmic Anatomy

The structure of the avian eye is truly remarkable. The globes are very large and may outweigh the brain. The globe may have one of three shapes: flat, globose, or tubular. The flat shape is most common and has a short anteroposterior axis and a partly concave ciliary region. The posterior segment is hemispheric, increasing retinal surface area. Crows and diurnal raptors have a globose globe, in which the ciliary region protrudes farther from the posterior segment but is still somewhat concave. This shape contributes to high-resolution distance vision. Owls have a tubular globe, in which the concave intermediate zone (ciliary region) is elongated in the anteroposterior axis. The shape of the avian globe is formed and maintained by scleral hyaline cartilage along with 10 to 18 scleral ossicles. The cartilage is located in the posterior sclera, and the ossicles in the ciliary region. In addition to structural rigidity, these bones contribute to accommodation, becoming a buttress for ciliary muscle action on the lens. The globe fits snugly into the bony orbit, which is large, shallow, and incomplete. A thin bony septum separates the two eyes. The six of the extraocular muscles common to mammals are present (four recti, superior and inferior oblique) but are poorly developed, and therefore there is minimal globe movement. The retractor bulbi muscle is not present but rather is replaced by the pyramidalis and quadratus muscles, which are responsible for third eyelid movement. These two muscles are suspected to be evolutionarily derived from retractor bulbi of crocodilians.

Birds have upper and lower eyelids, of which the lower eyelid is more mobile. Meibomian glands are absent. The third eyelid is 90% transparent, arising at the dorsomedial orbit and covering the globe by extending ventrolaterally. Movement is

achieved by contraction of the pyramidalis muscle as it loops through the quadratus muscle posterior to the globe. The leading edge of the third eyelid contains a marginal plait that acts much like a squeegee, collecting and distributing the tear film along the corneal surface. The tear film is produced by lacrimal and harderian glands located ventrolateral to the globe and adjacent to the base of the third eyelid, respectively. Two lacrimal puncta are present, allowing drainage of tears through the nasolacrimal duct and into the nasal cavity.

The anterior uvea of birds has a distinct role in accommodation. The iris musculature is predominantly striated, although limited amounts of smooth muscle and myoepithelium exist within the dilator muscle. Therefore pharmacologic dilation must involve the use of curariform neuromuscular blocking agents applied either intracamerally or topically. Topical use of such agents frequently does not provide sufficient mydriasis, although the inherent risk of intracameral injection limits this route. The ciliary muscles are also striated, allowing quick accommodation. Accommodation in the avian eye is accomplished through three mechanisms: change in the corneal curvature, deformation of the lens, and anterior movement of the lens. Three muscles are involved in accommodation. The muscle of Crampton is the most anterior ciliary muscle. It extends from the innermost scleral ossicles to the corneoscleral junction. With contraction, the radius of curvature of the cornea is altered. Brücke's muscle and Müller's muscle are posterior to the muscle of Crampton. Contraction of these muscles exerts force on the ciliary processes that are fused to the lens capsule equator. As these muscles act, the lens is squeezed or moved anteriorly to assist in accommodation. Similar to the muscle of Crampton, Brücke's muscle and Müller's muscle insert along the scleral ossicles and push against them during contraction. Using these three mechanisms, the avian eye has an accommodation range from 2 to 50 D.

To allow faster accommodation, the avian lens is softer and more pliable than lenses of mammals. It is relatively spherical in nocturnal species and flattened anteriorly in diurnal species. An interesting modification of the equatorial lens is the presence of the ringwulst, or annular pad located adjacent to the fused ciliary processes. It consists of hexagonal lens fiber cells arranged in a radial fashion and likely contributes to accommodation.

The avian fundus is perhaps the most interesting of all species. Indirect ophthalmoscopy reveals a nontapetal, anangiotic retina with a large, pigmented, vascular pecten extending into the vitreous. The pecten overlies the optic disc, obscuring its view. The three shapes of pecten that have been described are pleated (found in most species), vaned (present in ostriches), and conical (found in the kiwi). Although numerous functions have been proposed for the pecten, it likely serves a nutritional role and may contribute to aqueous production. Depending on the species, the distribution and ratio of rods to cones in the retina vary. A predominance of double cone photoreceptors is present that each contain an oil droplet in the chief cone. A remarkable adaptation further increasing visual acuity is the presence of a fovea. Most domestic species are afoveate, and others are monofoveate. However, many diurnal raptors and others (such as hummingbirds) are bifoveate, having a fovea centrally and another laterally. The lateral fovea is believed to be important for binocular vision, and the central fovea for monocular vision. The combination of several ocular adaptations along with a large occipital cortex (called the visual wulst) provides some birds with visual acuity several times better than that of humans.

Several ocular anatomic modifications exist in the avian eye that result in faster accommodation and possibly enhanced vision compared with mammals.

Ophthalmic Disease

Trauma

In raptors and wild passerines, blunt trauma is a common cause of ophthalmic disease. Clinical signs may be confined only to the globe, but usually other systemic signs are evident. Ophthalmic signs include periocular bruising, subconjunctival hemorrhage (Figure 20-9), conjunctivitis, hyphema, anterior uveitis, and posterior segment abnormalities. The posterior segment is most commonly affected, most likely because of the large size of the globe, its tight fit in the orbit, and its inflexibility due to scleral ossicles. A coup-contrecoup injury may cause anteroposterior shifting of the vitreous and lead to retinal detachment, retinal tears, vitreous and choroidal hemorrhage, or avulsion of the pecten.

The systemic condition of the bird should first be evaluated, and supportive care given. When only anterior segment abnormalities are present, prognosis for vision is sometimes good. If present, anterior uveitis should be treated with a topical NSAID several times daily. Topical steroids should be used with caution, because their systemic absorption may lead to generalized immunosuppression. When the posterior segment is involved, prognosis for vision is usually guarded to poor. Because vision is integral to catching prey, affected birds are frequently euthanized. Owls and other auditory hunters may be an exception to this rule and can possibly be rehabilitated and released into the wild. However, some authorities have suggested that changes in facial (and therefore aural symmetry) with altered globe size (buphthalmos or phthisis) or subsequent to enucleation may affect the birds' ability to hunt and survive using auditory cues. In pet birds or birds destined to a life in a rehabilitation facility, enucleation may be necessary if penetrating trauma or severe panophthalmitis is present. Enucleation

Figure 20-9. Subconjunctival hemorrhage in a finch secondary to blunt trauma. Erythema of the dorsal periocular skin is also present.

can be completed through either a transaural approach or a globe-collapsing technique.

Conjunctival Disease

Conjunctivitis is the most common ocular disease in captive birds and nonraptor species. Clinical signs usually involve a serous or seropurulent discharge, blepharospasm, conjunctival hyperemia, and increased preening activity. Causes include trauma from foreign bodies, excessive preening/pecking, environmental irritants, and infectious agents such as parasites, bacteria, virus, and fungi. Obtaining a thorough history and examining the bird in its natural environment may facilitate diagnosis. After performing a complete ophthalmic examination, the practitioner should obtain conjunctival swabs for cytologic examination and appropriate culture.

Traumatic conjunctivitis may be secondary to accumulation of foreign material in the conjunctival sac or excessive preening or pecking by cage mates. Foreign bodies can be gently removed through the use of copious lavage with balanced salt solution or manually with fine forceps. If trauma is secondary to the housing situation, separation of the affected bird is warranted. Treatment may not be necessary once the offending agent is removed. A broad-spectrum antibiotic drop, such as a triple-antibiotic formulation, may be used as needed. Topical steroids should be used with caution, because systemic toxicity can occur.

Several parasites, including *Oxyspirura, Thelazia,* and *Cryptosporidium* spp., have been demonstrated to cause avian conjunctivitis. Pet birds, especially budgerigars, are more commonly infested with the scaly face mite *Knemidokoptes pilae*. Clinical signs include scaly, proliferative lesions of the legs, cere, and eyelids. Diagnosis is made through identification of the organism in skin scrapings. Treatment involves systemic administration of ivermectin, diluted 1:10 in saline and given at 200 µg/kg subcutaneously or orally. Treatment is usually curative.

Bacteria and viruses are the most commonly diagnosed infectious causes of conjunctivitis in birds. Bacterial conjunctivitis may be an extension of infection from the upper respiratory system or secondary to an opportunistic infection by the normal conjunctival flora. A thorough examination of the choanal region and periorbital sinuses is recommended. Offending bacteria include *Pseudomonas, Staphylococcus, Pasteurella, Citrobacter, Escherichia coli,* and *Klebsiella*. *Mycoplasma* spp. are not frequently isolated from the normal conjunctiva but are likely a common cause of conjunctivitis. *Mycoplasma* is contracted through inhalation or direct contact and is usually associated with an upper respiratory infection. Diagnosis is difficult and may be aided by PCR analysis of conjunctival, sinus, or tracheal swabs. Because mortality can be high, aggressive treatment with systemic tetracyclines or fluoroquinolones is recommended. For conjunctivitis not secondary to *Mycoplasma*, treatment is based on results of culture and sensitivity testing of isolates. The majority of gram-positive organisms are susceptible to triple-antibiotic preparations, and most gram-negative organisms to topical fluoroquinolones. If concurrent respiratory disease is present, additional systemic antimicrobial therapy should be initiated.

Numerous viruses have been implicated in avian conjunctivitis. Avian poxvirus is responsible for most cases of viral conjunctivitis in birds. Poxvirus is spread via infected mosquitoes. Clinical signs, which appear approximately 10 to 14 days after infection, include unilateral or bilateral ulcerative blepharitis and secondary conjunctivitis and ocular discharge. Scabs and raised papules may develop on the eyelids. Diagnosis is made through identification of eosinophilic, intracytoplasmic inclusion bodies (Bollinger bodies) from skin or mucosal scrapings. Rhinitis commonly accompanies the blepharoconjunctivitis. Treatment is supportive, involving gentle cleaning of the eyelid margins and topical application of a broad-spectrum antibiotic for secondary bacterial infections. Other, less common viruses causing conjunctivitis in birds are adenovirus, reovirus, herpesvirus, and paramyxovirus (Newcastle's disease). Severe systemic signs, including death, are usually associated with these viruses.

LIZARDS, TURTLES, TORTOISES, AND CROCODILIANS

The class Reptilia is comprised of five orders: lizards, snakes, chelonians (turtles and tortoises), crocodilians, and the tuatara (New Zealand "lizard"). Snakes have several anatomic differences from the other reptiles and therefore are considered separately.

Ophthalmic Anatomy

Reptilian and avian eyes are remarkably similar. Except in certain geckos and the ablepharine skinks, well-developed eyelids are present, with the lower lid being more mobile than the upper. Chameleons are an exception because their palpebrae are constricted around the cornea and have limited movement. A lacrimal gland and a harderian gland are present ventromedial and dorsolateral to the globe, respectively. Tear secretions drain through an inferior punctum located in the ventromedial conjunctival sac and into the oral cavity. Chelonians do not have lacrimal puncta or a lacrimal duct, and therefore epiphora and periocular tear staining are commonly observed. A third eyelid is present and arises at the ventromedial orbit, although a true gland of the third eyelid as seen in mammals is absent. All extraocular muscles are present, but they are poorly developed, because reptiles tend to move their heads more than their eyes to scan the environment. Chameleons, however, have exceptional independent movement of each globe, permitting exact fixation on their prey. Scleral ossicles and cartilage are present, with the cartilage present from the posterior pole to the equator and the ossicles extending anteriorly. As in birds, these give shape and stability to the globe and serve as support for the ciliary muscle during accommodation. An annular or equatorial pad similar to the ringwulst of birds is present and plays a role in accommodation.

Reptilian eyes have a ciliary roll rather than the ciliary processes present in birds and mammals. The retina is avascular and receives nutrition from the choriocapillaris. The conus papillaris is an epithelium-lined, pigmented, highly vascular structure derived from the hyaloid and, like the pecten of birds, projects into the vitreous cavity (Figure 20-10) to provide nutrition for the retina. There is also a vast capillary network along its periphery. The conus regresses in crocodilians, giving the optic disc a melanotic appearance. All reptiles lack the choroidal tapetum typical of many mammals, but crocodilians have an accumulation of guanine crystals in the retinal pigmented epithelial cells (i.e., a retinal tapetum) that may aid

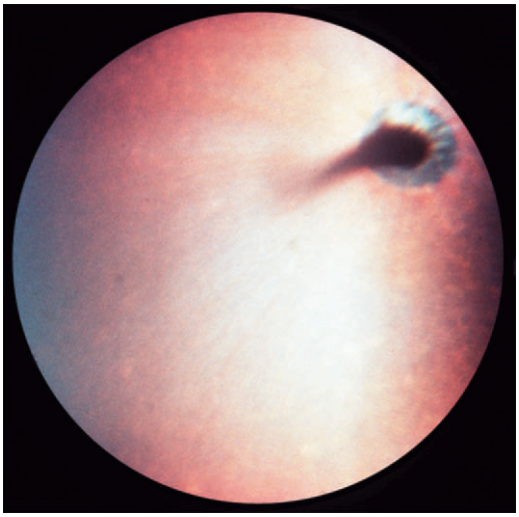

Figure 20-10. Conus papillaris of a gecko. The conus extends from the optic disc into the vitreous cavity.

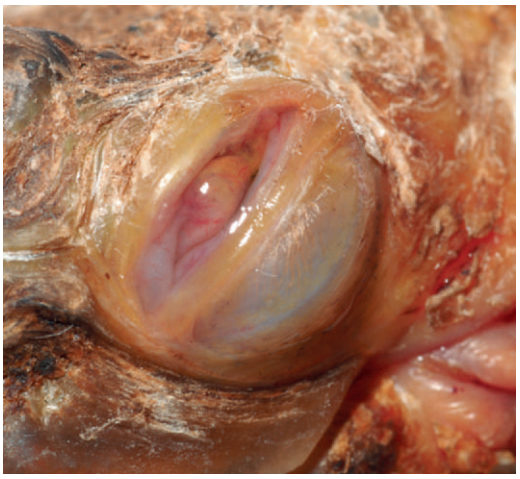

Figure 20-12. Severe blepharedema in a turtle with hypovitaminosis A.

nocturnal vision. The ratio of rods and cones in the retina varies greatly among species. Chameleons have a pure cone retina necessitated by their diurnal lifestyle and exact targeting of their prey. The ellipsoid region of the cone photoreceptors contains oil droplets, which are believed to function as light filters and to contribute to color discrimination.

Ophthalmic Disease

Suboptimal husbandry, including poor diet, inappropriate thermal gradient, overcrowding, overhandling, inappropriate humidity, poor sanitation, and environmental stressors, is the primary contributing factor to ophthalmic disease in captive reptiles. Ocular trauma from bedding material is common. Foreign material in the conjunctival fornices is frequently observed and may lead to conjunctivitis, ulcerative keratitis, or corneal perforation with resultant uveitis (Figure 20-11). After topical application of proparacaine, the foreign material can be removed either by gentle flushing or with fine forceps. Fluorescein staining will aid in evaluation of the integrity of the corneal surface. Corneal ulceration in reptilians is treated like that of mammals, with topical antibiotics and surgery if necessary. Parasympatholytic agents are ineffective and do not cause cycloplegia because of the abundance of striated iridal muscle, as in birds. Addressing the husbandry issues is paramount to avoiding future insults.

Figure 20-11. Superficial corneal ulcer secondary to trauma in a basilisk lizard.

Feeding an unbalanced diet, specifically one deficient in vitamin A, can lead to squamous metaplasia of ductal epithelium. This condition has been most commonly reported in young, fast-growing aquatic reptiles being fed primarily an insect- and/or meat-only diet. For unknown reasons, tortoises appear to be much less susceptible to hypovitaminosis A. With metaplasia, the orbital glands enlarge and the ducts become plugged with desquamated cells and debris, resulting in the ophthalmic clinical signs of palpebral edema and blepharoconjunctivitis. The palpebral fissure may be narrowed with edematous conjunctiva protruding through the fissure (Figure 20-12). Because the renal, gastrointestinal, and respiratory epithelia are also affected, early diagnosis and treatment are necessary to prevent death. In very early stages, changing the diet and adding a vitamin A supplement, such as cod liver oil, may reverse the clinical signs. However, as the disease progresses, parenteral administration of vitamin A at 1000 to 5000 IU weekly until clinical signs abate may be necessary. Parenteral administration of vitamin A must be done carefully, because oversupplementation will lead to epidermal sloughing.

The majority of ocular diseases in reptiles is secondary to poor husbandry.

Other ophthalmic diseases occur sporadically in reptiles. Congenital microphthalmos has been reported and may be associated with other craniofacial abnormalities. Abnormal environmental temperatures during gestation and/or incubation of eggs may lead to congenital abnormalities. Conjunctivitis in reptiles has been associated with three viruses: herpesvirus, iridovirus, and virus "X." Other mucosa-lined organ systems are usually involved, and stomatitis, rhinitis, and pneumonia are frequently present. Fibropapillomas in marine turtles often occur as aggregates around the eyelids and may become large enough to obscure vision and prevent normal feeding. The cause of the fibropapillomas is unknown, although replicating herpesvirus has been identified within the masses. Bacterial ocular infections are not common and when present are likely a manifestation of septicemia. Uveitis with hypopyon has been

Figure 20-13. Complete cataract in a monitor lizard secondary to uveitis. Note the focal posterior synechia ventrally.

observed in septicemic reptiles. Cataracts are uncommon but may occur secondary to uveitis (Figure 20-13).

SNAKES

Ophthalmic Anatomy

Although a member of the class Reptilia, snakes have several unique anatomic alterations separating them from lizards, chelonians, and crocodilians. Like geckos and ablepharine skinks, snakes possess not eyelids but a clear, transparent spectacle. The spectacle is formed embryologically by fusion of the eyelids. Although it is transparent, there is a vast vascular network within the spectacle that has been demonstrated by microsilicone injection. The spectacle is, in essence, skin and prevents topical medications from reaching the ocular surface. The outermost layer or epidermal aspect of the scales is normally shed through a process called *ecdysis*. Ecdysis depends on food intake, humidity, air temperature, age, and presence or absence of systemic disease. Just before ecdysis the skin dulls, including the spectacle; at this point the snake is severely visually impaired and may become more aggressive. The outer skin and spectacle should be shed in one complete piece but may not do so, depending on systemic health and husbandry conditions.

Snakes do not have a lacrimal gland or third eyelid but do possess a well-developed harderian gland, located posterior to the globe. Oily secretions from the harderian gland bathe the subspectacular space and exit through the lacrimal duct into the mouth, as in lizards. This direct communication between the mouth and subspectacular space may allow ascending infections.

Unlike in other reptiles and birds, there is no cartilage present in the sclera of snakes. The cornea is relatively thin with only a single layer of epithelium. A thick corneal epithelium is not necessary because the cornea is protected by the spectacle. The anterior chamber is narrow, secondary to a large spherical lens. As in other reptiles and birds, the iridal musculature is striated. Accommodation in the snake is believed to occur via action of a muscle at the root of the iris that presses on an anterior lens pad to alter lens shape. In addition, the ciliary muscle exerts force on the vitreous, causing forward displacement of the lens. The retina is similar to that of mammals in that it contains both rods and cones; the ratio of rods to cones varies significantly between species, most likely owing to their diurnal or nocturnal lifestyle. Unlike reptiles, snakes do not have oil droplets within their retinas. Retinal nutrition likely comes from the choroid, although a membrana vasculosa is present within the vitreous that may have some nutritive role. The optic nerve is similar to that in reptiles, but a conus papillaris is not present. Ophthalmoscopically, the central aspect of the optic disc is commonly melanotic, similar to that in crocodilians. This feature is suspected to be a remnant of the conus papillaris that regressed during ocular development. The conus may persist in the viper.

Almost all reported ophthalmic disease in snakes concerns the anterior segment, most likely owing to the difficulty examining the fundus. Not only does the small eye present a challenge, but mydriasis is difficult to achieve. Topical medications are not effective because of the presence of the spectacle. Additionally, the striated muscle in the iris would require the use of curariform neuromuscular blocking agents for paralysis. General anesthesia with injectable or inhalant anesthetics may produce sufficient mydriasis for fundus examination.

Spectacular Disease

Retained spectacles, subspectacular abscesses, and pseudobuphthalmos are the most common ophthalmic diseases of snakes. Spectaculitis has also been reported secondary to mites of the *Ophionyssus* spp. that tend to congregate around the spectacle, where they are able to receive a blood meal. Spectacular opacification has been demonstrated after contact with aerosolized organophosphates or polyurethane solvents. Mycotic keratitis has also been described, likely secondary to penetrating injury of the spectacle and cornea.

Dysecdysis is abnormal shedding of the epidermal or superficial layer of the skin. When it occurs over the eye, the spectacle is retained and forms a cloudy, wrinkled opacification (Figure 20-14) that obscures vision. Many factors may contribute to dysecdysis, but poor husbandry, specifically insufficient humidity, is the most common cause of retained spectacles. Initial treatment is conservative, involving correction of husbandry issues. Increasing the cage humidity to at least 50% to 60% and ensuring proper hydration may be all that is necessary for dislodgement of the retained epidermal layers. If the condition persists, the snake can be soaked in water or topical acetylcysteine can be applied to help loosen the spectacle. Most times, after the husbandry issues are addressed, the retained spectacle is shed at the next ecdysis. If not, manual

Figure 20-14. Retained spectacle in a Burmese python.

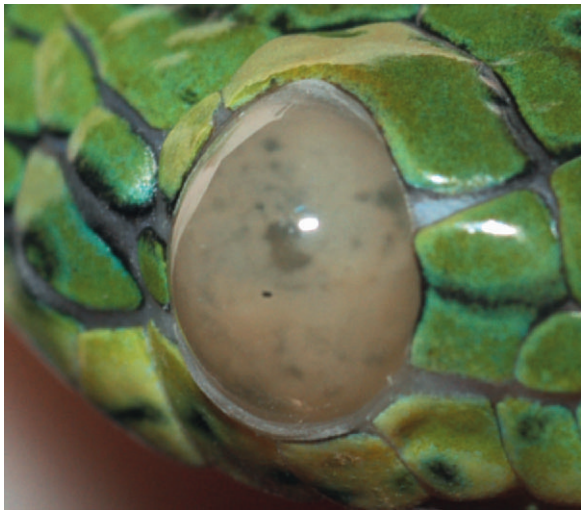

Figure 20-15. Subspectacular abscess in a green tree snake. Note the distension of the spectacle with purulent exudate.

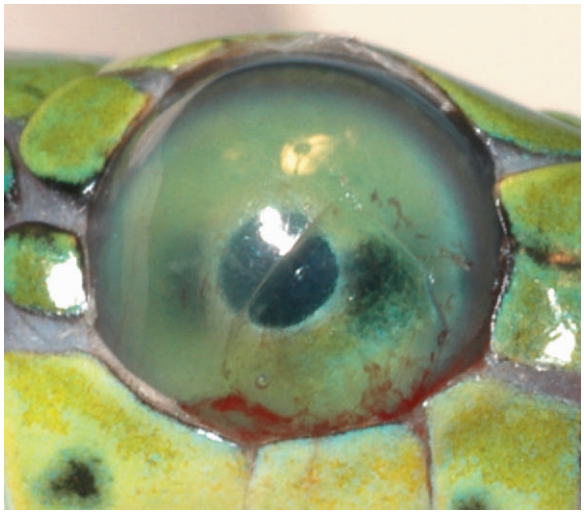

Figure 20-16. Right eye of the snake in Figure 20-15 after a wedge spectaculectomy. Note the wedge-shaped incision in the ventral spectacle that allows drainage and treatment of the subspectacular space.

removal may be necessary. This procedure usually warrants referral because it must be done with magnification, fine forceps, and extreme caution. If more than just the outer layers of the spectacle are removed, a severe exposure keratitis will ensue, potentially requiring enucleation.

Subspectacular abscesses occur when there is an accumulation of purulent debris between the spectacle and cornea within the subspectacular space (Figure 20-15). Infection arises within the subspectacular space via three potential routes: penetrating spectacular trauma, ascending infection through the lacrimal duct from the mouth, and hematogenous spread. On examination, anterior bulging of the spectacle is evident. The bulging is caused by a grossly distended subspectacular space filled with caseous purulent debris. Evaluation and treatment for septicemia and stomatitis are necessary, along with ophthalmic treatment; otherwise recurrence is likely. Treatment is surgical and is best performed by an ophthalmologist. After either injectable or inhalant anesthesia is achieved, magnification and Vannas scissors are used to resect a 30-degree spectacular wedge ventrally (Figure 20-16). Particular care must be taken not to injure the cornea. After partial spectacular resection, the purulent debris is lavaged from the subspectacular space with balanced salt solution. Aerobic, anaerobic, and fungal culture of the debris should be obtained. *Pseudomonas* spp. have been implicated as the causative agent, although other organisms may be present. Pending results of culture and sensitivity testing, a broad-spectrum antibiotic is applied topically until the next ecdysis. Fluoroquinolones and aminoglycosides have been efficacious in clinical cases. Systemic antimicrobial agents may be indicated if there are clinical signs of disease elsewhere.

Gross distention of the subspectacular space with clear fluid from the harderian gland occurs secondary to occlusion of the lacrimal duct. Because the globe appears (but is not) larger, this condition has been referred to as pseudobuphthalmos, but bullous spectaculopathy is a more appropriate term. Causes of lacrimal duct obstruction include ulcerative stomatitis, congenital atresia, cicatrization from trauma or burns, and blockage from an external granuloma or neoplastic mass. Treatment involves creating a new drainage pathway. A spectacular wedge resection, as described previously, is efficacious although it may need to be repeated after ecdysis because of healing of the spectacular incision. Conjunctivoralostomy has been performed, although it requires significant skill and should not be attempted without proper training.

Retained spectacle, subspectacular abscess, and pseudobuphthalmos are the most common ocular diseases observed in snakes.

AMPHIBIANS

Ophthalmic Anatomy

Amphibians are classified into three orders, tailless (Anurans such as frogs and toads), tailed (Urodelas such as salamanders and newts), and legless (Apoda). Many Apoda species live underground and have either no or rudimentary eyes. The anuran eye is the most highly developed of the three and has been extensively used in research. The structure of the adnexa depends on the animal's habitat. Larval amphibians and aquatic adults do not have eyelids. Urodelas have well-formed eyelids. Anurans have poorly developed, immobile upper eyelids and a transparent ventral conjunctival fold serving as a "false third eyelid" or lower eyelid. The conjunctival fold moves dorsally to cover the cornea when retractor bulbi muscle contraction causes enophthalmos. This contraction not only is important for corneal protection but also serves a vital role in swallowing. With retraction, the globe and associated musculature contact the oropharynx and aid in pushing the prey material into the esophagus. The globe is returned to its normal position by a levator bulbi muscle located posteriorly. The other six typical extraocular muscles are present, but their function is negligible. The tear film is derived from a lacrimal gland, a harderian gland, and superior or inferior (in the case of terrestrial salamanders) eyelid glands. The presence of lacrimal puncta and a nasolacrimal duct varies among species, but these structures are usually absent.

The uvea is quite peculiar in amphibians. The iris can be very colorful owing to carotenoid pigments and guanine crystals. A myoepithelial sphincter and dilator muscle is present, although pupil movement is minimal. The shape of the pupillary aperture varies dramatically at rest and with miosis but is circular with mydriasis. The ciliary body is triangular with numerous folds, which may continue to the pupillary margin and result in a nodule. As in elasmobranchs, a protractor lentis muscle is present. Contraction of the muscle moves the lens anteriorly, aiding in accommodation. The lens is large and spherical. Interestingly, some species are capable of regenerating the lens from either the pigmented epithelial cells of the dorsal iris or from the cornea, like tail and limb regeneration after amputation. Examination of the fundus is difficult but when accomplished demonstrates a remarkable vascular preretinal membrane within the vitreous. Urodelas that do not have a vascular preretinal membrane receive all retinal nutrition from the choroid. The retina is similar to that of reptiles, with some cone photoreceptors having oil droplets.

Ophthalmic Disease

Only sporadic cases of amphibian ocular disease are reported in the literature and are usually associated with systemic disease. *Redleg*, one of the most common systemic diseases of Anurans, is a catchall term for infection secondary to gram-negative bacteria including *Aeromonas hydrophila* and *Citrobacter freundii*. Redleg septicemia in fire-bellied toads was found to result in diffuse corneal edema, hyphema, hypopyon, iridocyclitis, cataract, chorioretinitis, and, sometimes, periocular blood-filled blisters. Experimentally induced septicemia with *Flavobacterium indologenes* caused anterior uveitis and secondary corneal edema in leopard frogs. Affected animals usually do not show response to therapy, and morbidity is high. Corneal ulceration infrequently occurs and may progress to bullous keratopathy. Because of the size of the animals, systemic toxicity after topical application of antibiotics is possible. Gentamicin diluted to 2 mg/mL has been effective and reported to be safe. Alternatively, the false third eyelid can be sutured to the upper eyelid to provide protection of the corneal surface.

The most commonly encountered and best studied ocular disorder in amphibians is lipid keratopathy. It was first reported in Cuban tree frogs and has since been identified in several other species. In hylid, leptodactylid, and ranid species, generalized xanthomatosis occurred, affecting not only the cornea but also brain, some viscera, peripheral nerves, periarticular soft tissues, and digital pads. Ophthalmic signs appear similar to those of corneal arcus, including a circumferentially progressive sparkly or creamy white anterior stromal infiltrate consisting of cholesterol and lipid-laden macrophages. Classically, excessive lipid mobilization associated with oogenesis was suspected as the cause because all affected frogs were female. A later study demonstrated that diet may be responsible, with frogs fed high-cholesterol diets demonstrating corneal lipid deposition independent of gender or stage of vitellogenesis. Nutritional therapy may slow the accumulation of lipid but is rarely curative. If lipid keratopathy is left untreated, diffuse corneal vascularization and superficial melanosis may occur (Figure 20-17).

Figure 20-17. Lipid keratopathy in an African bullfrog. Corneal melanosis and superficial vascularization are also present.

BIBLIOGRAPHY

Abrams GA, et al. (2002): Conjunctivitis in birds. Vet Clin North Am Exot Anim Pract 5:287.

Andrew SE (2002): Corneal diseases of rabbits. Vet Clin North Am Exot Anim Pract 5:341.

Bagley LH, Lavach D (1995): Ophthalmic diseases in rabbits. California Vet 49:7.

Bauck L (1989): Ophthalmic conditions in pet rabbits and rodents. Comp Cont Educ 11:258.

Beaumont SL (2002): Ocular disorders of pet mice and rats. Vet Clin North Am Exot Pract 5:311.

Bellairs Ad'A (1981): Congenital and developmental diseases, in Cooper J, Jackson OF (editors): Diseases of the Reptilia. Academic Press, London, p. 469.

Burling K, et al. (1991): Anatomy of the rabbit nasolacrimal duct and its clinical implications. Vet Comp Ophthalmol 1:33.

Coke RL, Couillard NK (2002): Ocular biology and diseases of Old World chameleons. Vet Clin North Am Exot Anim Pract 5:275.

Cullen CL, et al. (2000): Diagnostic ophthalmology. Can Vet J 41:327.

Davidson MG (1986): Canine distemper virus infection in the domestic ferret. Comp Cont Ed 8:448.

Donnelly TM (1997): What's your diagnosis? Blood-caked staining around the eyes in Sprague-Dawley rats. Lab Anim 26:17.

Duke-Elder S (1958): The eyes of amphibians, in System of Ophthalmology, Vol I: The Eye in Evolution. Mosby, St. Louis, pp. 333-351.

Duke-Elder S (1958): The eyes of birds, in System of Ophthalmology, Vol I: The Eye in Evolution. Mosby, St. Louis, pp. 397-427.

Duke-Elder S (1958): Reptiles, in System of Ophthalmology, Vol I: The Eye in Evolution. Mosby, St. Louis, pp. 353-395.

Elkan E, Zwart P (1967): The ocular disease of young terrapins caused by vitamin A deficiency. Pathol Vet 4:201.

Felchle LM, Sigler RL (2002): Phacoemulsification for the management of *Encephalitozoon cuniculi*-induced phacoclastic uveitis in a rabbit. Vet Ophthalmol 5:211.

Fox JG, et al. (1979): Congenital entropion in a litter of rabbits. Lab Anim Sci 29:509.

Glorioso JC, et al. (1974): Microbiological studies on septicemic bullfrogs *(Rana catesbeiana).* Am J Vet Res 35:1241.

Good KL (2002): Ocular disorders of pet ferrets. Vet Clin North Am Exot Anim Pract 5:325.

Greenacre CB (2005): Viral diseases of companion birds. Vet Clin North Am Exot Anim Pract 8:85.

Harcourt-Brown FM, Holloway HKR (2003): Encephalitozoon cuniculi in pet rabbits. Vet Rec 152:427.

Jacobsen ER (1977): Histology, endocrinology, and husbandry of ecdysis in snakes. Vet Med Small Anim Clin 72:275.

Janssens G (2002): Ophthalmic diseases in the rabbit. Eur J Comp Anim Pract 12:61.

Kashuba C (2005): Small mammal virology. Vet Clin North Am Exot Anim Pract 8:107.

Keller CB, Shilton CM (2002): The amphibian eye. Vet Clin North Am Exot Anim Pract 5:261.
Kern TJ (1997): Rabbit and rodent ophthalmology. Semin Avian Exot Pet Med 6:138.
Krogstad AP, et al. (2005): Viral diseases of the rabbit. Vet Clin North Am Exot Anim Pract 8:123.
Langlois I (2005): Viral diseases of ferrets. Vet Clin North Am Exot Anim Pract 8:139.
Li X, et al. (1998): Neoplastic diseases in ferrets: 574 cases (1968-1997). J Am Vet Med Assoc 212:1402.
Loerzel SM, et al. (2002): Vecuronium bromide, phenylephrine and atropine combinations as mydriatics in juvenile double-crested cormorants *(Phalacrocorax auritus).* Vet Ophthalmol 5:149.
Lucas J, et al. (2000): *Mycobacterium genavense* infection in two aged ferrets with conjunctival lesions. Aust Vet J 78:685.
Marini RP, et al. (1989): Proven or potential zoonotic diseases of ferrets. J Am Vet Med Assoc 195:990.
Mauel MJ, et al. (2002): Bacterial pathogens isolated from cultured bullfrogs *(Rana castesbeiana).* J Vet Diagn Invest 14:431.
McCalla TL, et al. (1997): Lymphoma with orbital involvement in two ferrets. Vet Comp Ophthalmol 7:36.
Mead AW (1976): Vascularity of the reptilian spectacle. Invest Ophthalmol Vis Sci 15:587.
Mikaelian I, et al. (1994): Comparative use of various mydriatic drugs in kestrels *(Falco tinnunculus).* Am J Vet Res 55:270.
Miller PE (1997): Ferret ophthalmology. Semin Avian Exotic Med 6:146.
Miller PE, Dubielzig RR (1995): Autosomal dominant microphthalmia, cataract, and retinal dysplasia in a laboratory colony of ferrets. Invest Ophthalmol Vis Sci 36(Suppl):S64.
Miller PE, et al. (1993): Cataracts in a laboratory colony of ferrets. Lab Anim Sci 43:562.
Miller PE, Pickett JP (1989): Zygomatic salivary gland mucocele in a ferret. J Am Vet Med Assoc 194:1437.
Millichamp NJ (1990): Lipid keratopathy in frogs: histopathology and biochemistry. Invest Ophthalmol Vis Sci 15:587.
Millichamp NJ, et al. (1986): Conjunctivoralostomy for treatment of an occluded lacrimal duct in a blood python. J Am Vet Med Assoc 9:1136.
Millichamp NJ, et al. (1983): Diseases of the eye and ocular adnexa in reptiles. J Am Vet Med Assoc 183:1205.
Moore CP, et al. (1987): Anterior corneal dystrophy of American Dutch belted rabbits: biomicroscopic and histopathologic findings. Vet Pathol 24:28.
Munger RJ, et al. (2002): Spontaneous cataracts in laboratory rabbits. Vet Ophthalmol 5:177.
Murphy CJ (1987): Raptor ophthalmology. Comp Cont Educ 9:32.
Murphy CJ, Dubielzig RR (1993): The gross and microscopic structure of the golden eagle *(Aquila chrysaetos)* eye. Prog Vet Comp Ophthalmol 3:74.
Murphy CJ, et al. (1983): Enucleation in birds of prey. J Am Vet Med Assoc 11:1234.
Mutti DO, et al. (1992): Retinoscopic measurement of the refractive state of the rat. Vision Res 32:583.
Ramer JC, et al. (1996): Effects of mydriatic agents in cockatoos, African gray parrots, and blue-fronted Amazon parrots. J AmVet Med Assoc 208:227.
Ridder, WH, et al. (2002): Causes of cataract development in anesthetized mice. Exp Eye Res 75:365.
Rothwell TL, Everitt AV (1986): Exophthalmos in ageing rats with harderian gland disease. Lab Anim 20:97.
Roze M, et al. (2001): Comparative morphology of epicorneal conjunctival membranes in rabbits and human pterygium. Vet Ophthalmol 4:171.
Ryland LM, et al. (1983): A clinical guide to the pet ferret. Comp Cont Ed 5:25.
Seely JC (1987): The harderian gland. Lab Anim 16:33.
Stiles J, et al. (1997): *Encephalitozoon cuniculi* in the lens of a rabbit with phacoclastic uveitis: confirmation and treatment. Vet Comp Ophthalmol 7:233.
Wellehan JF, Johnson AJ (2005): Reptile virology. Vet Clin North Am Exotic Anim Pract 8:27.
Williams DL (2002): Ocular disease in rats: a review. Vet Ophthalmol 5:183.
Williams DL (2002): Rabbits, in: Petersen-Jones S, Crispin S (editors): Manual of Small Animal Ophthalmology, 2nd ed. British Small Animal Veterinary Association, Gloucester, UK, pp. 276-284.
Williams DL (1996): Ophthalmology, in Mader DR (editor): Reptile Medicine and Surgery. Saunders, Philadelphia, pp. 175-184.
Williams DL, Whitaker BR (1994): The amphibian eye—a clinical review. J Zoo Wildl Med 25:18.