Ostriches, emus, and rheas are among birds that are highly susceptible to avian influenza, and various strains have been identified in ratites, including H7N1, H5N9, H5N2, H9N2 and H10N7. Chicks are more susceptible than adults and secondary respiratory and intestinal infects sometimes mask the underlying viral infection. Despite the highly contagious nature of avian Paramyxovirus serotype 1 (Newcastle disease) during an outbreak, chronic neurologic disease in ostriches tends to spread relatively slowly through the population, is usually limited to a small number of birds (mostly juveniles) and may therefore be controlled with vaccinations. Emus have tested serologically positive but no cases of clinical disease have been described. In contrast to the pathogenesis in most other avian species, eastern equine encephalitis virus does not cause neurological disease in emus and rheas but shows a unique visceral tropism, primarily leading to GI symptoms. Avian poxvirus may manifest as either wet or dry forms. Vaccination with fowl pox vaccines has proven effective in ostriches. Bornavirus infection has been reported to have resulted in outbreaks of paresis and general malaise, followed by anorexia, depression and death from dehydration in ostrich chicks in intensive farming conditions. Both adenovirus and circovirus were isolated from sick ostrich chicks and were suspected to be implicated in the “chick-fading syndrome. Miscellaneous viral pathogens reported to ratites include infectious bursal disease virus (only experimental disease, no natural infections reported), rotaviruses, orthoreoviruses adenoviruses (serologically positive samples or viral
isolation, but clinical relevance remains unclear), and Crimean-Congo hemorrhagic fever (CCHF), a tick-transmitted disease occurring across the African continent that causes a short, symptomless viremia in sheep, cattle, and ostriches and has fatal zoonotic potential (through handling of tick-infested ostriches or through contact with infect ostrich blood during slaughter).

Two cases of spongiform encephalopathy in adult ostriches in German zoos have been histologically described, but the etiology was never confirmed with electron microscopy.

Diseases relevant to penguins include eastern equine encephalitis (EEE) and West Nile virus (WNV). Both EEE and WNV have been reported in Spheniscid penguins, and these penguins may have high rates of morbidity and mortality in response to this disease.

Vaccination is recommended for susceptible species. At this time, no vaccines produced specifically for birds are commercially available. Two vaccines developed for horses have been used. Innovator (Pfizer) is a killed vaccine. Its efficacy, as measured by serologic titers, differ in different avian species. Recommendation are to vaccinate susceptible birds three times at 3-4-week intervals and then annually 1 month prior to mosquito season. Recombitek (Merial) is a live recombinant canarypox vaccine. Anecdotal reports of this being used exist, but efficacy is currently unknown.

EEE is caused by an alphavirus. This disease was reported in a group
of African penguins housed outdoors. Common signs include acute anorexia, lethargy, intermittent vomiting, bile-stained diarrhea, and self-isolation. A killed vaccine against EEE is available for horses, and although the required dose and efficacy for penguins has not been determined, some institutions in EEE-endemic areas have opted to use this vaccine.

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Marsupialia (Marsupials)
Chapter 33   Page 273
PREVENTIVE MEDICINE
Larry Vogelnest

A range of vaccines have been used in macropods and include a multi-serotype vaccine against *Dichelobacter nodosus* for oral necrobacillosis (lumpy jaw), a canine vaccine against *B. bronchiseptica*, an inactivated encephalomyocarditis virus vaccine and either human or equine tetanus toxoid or a multivalent clostridial vaccine for tetanus prophylaxis. Responses are variable, and sterile abscesses and swelling frequently develop at injection sites with some vaccines. Vaccination of koalas against *B. bronchiseptica* using a canine vaccine appears to reduce the incidence of mortality from infection with *Bordetella spp*. In rabies-endemic countries where the incidence of rabies is high, marsupials in zoos may be at high risk of exposure. In such cases, vaccination is recommended, however, the efficacy of rabies vaccination in marsupials has not been established.
VACCINATION OF PROSIMIANS

Cathy V. Williams

Despite lack of information regarding titer responses of prosimians to rabies vaccination, precaution warrants vaccinating individuals with a killed vaccine if a risk of exposure to rabies vectors exists. Vaccination against tetanus is elective, as no information exists regarding the tendency of prosimians to develop the condition. Routine periodic physical examinations, dental prophylaxis, and laboratory testing under anesthesia are recommended for captive prosimians to detect problems early when treatment is most effective.
All monkeys are susceptible to tetanus. Infection, through wounds or penetrating injuries and subsequent neurotoxin production usually result in fatal disease. So all the animals should be routinely vaccinated with tetanus toxoid, according to human vaccination recommendations. In rabies-endemic areas, NW and OW monkeys in outdoor exhibits should be vaccinated for rabies. Only an inactivated (killed) vaccine should be used to avoid the risk of vaccine-induced disease that may occur when attenuated (modified live) vaccine are used. For both tetanus and rabies vaccination, the vaccine dose is generally adjusted for the smaller size of NW and OW monkeys (typically 0.05-0.1 ml. for callitrichids, 0.25 ml. for medium-sized primates, and 0.5 ml. for larger primates).

Although monkeys are susceptible to measles infection, because of the decline in incidence of human disease achieved through human vaccinations, effective preventive health protocols for monkeys, and adherence to personal protective procedures by staff, monkeys are not routinely vaccinated for this disease. If measles vaccination is elected, care should be exercised in selecting the specific vaccine to minimize the risk of vaccine-induced disease, since most measles vaccines are attenuated (modified live) vaccine viral strains. Other vaccinations such as those against pneumococcosis or leptospirosis may be administered on a case-by-case basis or as a result of local conditions or facility-specific considerations. In these situations, all attenuated vaccines should be employed cautiously because of the risk of vaccine-induced disease, and it is advisable to contact other veterinary practitioners to determine what attenuated vaccines have been safely used in the species of concern.
IMMUNOPROPYLAXIS
Hayley Weston Murphy
Table 38-4
Gives the 2012 American Academy of Pediatrics immunization schedule.

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Lagomorpha (Pikas, Rabbits, and Hares)
Chapter 41
Jennifer E. Graham
No vaccine recommendations

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Rodentia
Chapter 42
Enrique Yarto-Jaramillo
No vaccine recommendations
VACCINATION OF CETACEANS

Christopher Dold
With input from Dr. Judy St. Leger and Dr. Todd Robeck of Sea World.

To date, only one vaccination has been regularly used in cetaceans housed in zoological parks. *E. rhusiopathie* is a well-established bacterial pathogen of dolphins and the use of the ER BAC PLUS vaccine (Zoetis Animal Health, New York), a liquid, serum-free, clarified bacterin vaccine has presented a welcome solution to the problem. Experience is limited although increasing and the surest indicator that the product provides protection is the apparent decline in new cases since the introduction of vaccine programs in several oceanaria. The product is licensed for use in swine, and any use in dolphins or whales is accordingly considered off-label. Still the most common practice is to follow the manufacturer’s handling instructions in detail, to exercise caution with the delivery of every vaccine to every animal, and to be prepared for a hypersensitivity reaction. The vaccine (2 ml.) should be delivered intramuscularly. The animal should remain in a shallow pool for 20 minutes to 1 hour after vaccination so that immediate intervention is possible in the event of a hypersensitivity reaction. Some clinicians recommend premedication with diphenhydramine. Appropriate vaccination scheduling is still under investigation, but annual vaccination after an initial vaccine and a 3-week booster are prudent, particularly in younger cetaceans.
PREVENTIVE MEDICINE

Some institutions have elected to vaccinate pinnipeds against rabies, WNV, and CDV with commercially available vaccines and most administer a heartworm preventive agent when D. immitis infection is endemic in dogs in the area.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Vaccine Type</th>
<th>Frequency</th>
<th>Notes</th>
</tr>
</thead>
</table>

VACCINATION OF NONDOMESTIC CANIDS

Luis R. Padilla and Clayton D. Hilton
Chapter 46 Page 465 TABLE 46-6
| Canine Distemper virus (CDV) | All canids: Recombinant canary pox vectored vaccine  
Modified live vaccines recommended for Mexican gray wolves (Canis lupus baileyi) and red wolves (C. rufus) | Begin at 6-9 week, booster every 2-3 weeks until 16-20 weeks, then yearly or check titers (Rodden AZA) | Recombinant canary pox vectored vaccine is safe, cannot induce CDV disease, and is recommended for all susceptible exotic carnivores |
| Rabies | All canids: Killed virus vaccine | Administer at 16 weeks, booster at 1 year of age, then annually or every third year depending on product used | A recombinant canary-pox vectored vaccine is available and may be used at veterinarian's discretion, especially for small canids, then booster yearly |
| Parvovirus | Killed vaccine safest  
Modified live vaccine used in red wolves, gray wolves, and adult maned wolves  
Maned wolves should be vaccinated | Begin at 6-9 weeks, booster every 2-3 weeks until 16-20 weeks, then yearly or check titers | Concerns with vaccine-induced disease in canids when using modified-live products, and strategy used for maned wolves may be appropriate for other species |
with a killed vaccine product until protective titers (>80) are present, then boosted with a modified live vaccine to avoid vaccine-associated disease

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Felidae
Chapter 47 Page 475

VACCINATION OF FELIDS

Nadine Lamberski

Vaccination protocols for carnivores have been recently reviewed (Fowler’s 7, pp 442-450, 2012). Vaccines recommended are divided into core vaccines (recommended for all felids) and noncore vaccines (optional, depending on the specific disease risk of the species and institution, not generally recommended). Vaccine-associated sarcomas have rarely been reported in nondomestic felids. Because of the lack of serologic studies and difficulty in performing challenge experiments on
non-domestic felids, specific information on the length of protections from vaccination is lacking. Specific recommendations for vaccination frequency cannot be made, although most institutions vaccinate adults every 1 to 3 years using the core vaccines. Core vaccines include rabies (killed, e.g., Imrab 3, Merial: or recombinant canarypox-vectored, e.g. PureVax Rabies, Merial) and feline panleukopenia, calicivirus, herpesvirus (killed, e.g. Fel-O-Vax PCT Plus, Boehringer Ingelheim). Noncore vaccines that should be considered only in species at risk include canine distemper virus (CDV) (recombinant canarypox-vectored, PureVax Ferret Distemper, Merial) and FeLV (killed).
Merial, Athens, GA) has been sown to be safe and efficacious and is the best choice for general mustelid protection against canine distemper virus. If an alternative modified-life canine distemper vaccine is used, it should be given separately and not in multiple forms, since immunosuppression and other untoward vaccine interactions might lead to disease. Ferret or mink cell culture-derived modified-live vaccine should never be used in mustelids. A modified-live canine distemper vaccine of primate kidney tissue cell origin, Onderstepoort type, is available in the United States (Galaxy D, Schering-Plough Animal Health Corporation, Omaha, NE) and has been proven to be safe and efficacious in hybrid black-footed ferrets and Siberian polecats. The only vaccine approved by the U.S. Department of Agriculture (USDA) for ferrets, Fervac-D (United Vaccines, Madison, WI) which is an egg-adapted strain, has induced anaphylactoid and anaphylactic reaction in some mustelids, so its use is not recommended.

Vaccination schedules for non-domestic species are extrapolated from studies of the domestic dog. Neonates receiving colostrum should be vaccinated every 3 to 4 weeks between 6 and 16 weeks of age. Colostrum-deprived neonates should be given two vaccinations administered at a 3 to 4 week interval and starting at 2 weeks of age because maternal antibodies acquired in utero may be absent by 4 to 6 weeks of age. Data on maternal antibody interference with vaccination in ferrets suggest that a final canine distemper vaccine should be administered after 10 weeks of age.

If an animal has an adverse reaction to canine distemper vaccine, an antihistamine (e.g. diphenhydramine hydrochloride, 0.5-2mg/kg, intravenously (IV) or intramuscularly (IM) or, for severe reactions, epinephrine (20 micrograms per kilogram (ug/kg), IV, IM, subcutaneously (SC), or intra-tracheally (IT), should be administer and supportive care provided. Mustelids are also vaccinated with a killed rabies vaccine (Imrab), although the efficacy of this vaccine has not been proven in exotic mustelids. Rabies should be given at 16 weeks of age to animals at risk of contracting rabies and given boosters annually thereafter.
VACCINATION OF PROCYONIDS AND VIVERRIDS

Edward Ramsay

Procyonids and Viverrids may be safely vaccinated with a canarypox-vectored canine distemper vaccine manufactured for domestic ferrets (Purvax, Merial, Duluth, MN). The immunogenicity of this vaccine has been shown in mustelids and giant pandas. Although challenge studies have not been performed in procyonids or viverrids, the author is unaware of clinical distemper in any of animals vaccinate with this product. Protocols for vaccination are similar to those for domestic dogs. Captive procyonids and viverrids may be vaccinated with a killed rabies virus vaccine. Recommendations regarding vaccination for parvovirus infection are more variable. Raccoons and palm civets should definitely be vaccinated, with a killed virus vaccine, if available. Vaccination of other procyonids and Viverrids for parvovirus is the decision of the attending clinician. Routine vaccination of red pandas against canine or feline parvovirus is not recommended at the time of writing this text.
VACCINATION OF URSIDAE

Darin M. Collins

Few vaccines are recommended or used in captive bears. Immunization with a killed-virus rabies vaccine may be warranted if bears are kept in an endemic area where local wildlife might gain access to the enclosure. Given the rarity of clinical disease and the limited exposure of most captive bears to canids, routine vaccination for ICH is not warranted. Captive giant pandas are usually vaccinated for canine distemper. Captive giant pandas have also been vaccinated, at various institutions, with killed-virus canine and feline parvovirus vaccines. Other ursids typically are not vaccinated for CDV or parvoviruses. In all bears, it is advisable to monitor antibody titers to ensure adequate immune response to vaccinations and track exposure to those diseases for which vaccines are unavailable or not used. Such titers may be analyzed from blood samples taken during routine and quarantine examinations.

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Hyaenidae
Chapter 51 Page 513
William Kirk Suedmeyer

PREVENTIVE CARE
On the basis of the apparent susceptibility of hyenas to CDV, it may be advisable to vaccinate hyenas against canine distemper using a recombinant canarypox vectored or killed vaccine. Although exposure to canid and felid viruses is prevalent in wild populations of spotted hyenas, clinical disease has not been documented. Rabies vaccination
with a killed product may be advisable in endemic areas. Rabies has been documented in wild spotted hyenas.
Rabies Vaccination appears to be protective. AJVR 67:1934-1936 2006

Annual vaccination for leptospirosis is recommended in black rhinos and possibly Indian rhinos. The animal should be observed for 30 minutes following vaccination because isolated cases of anaphylactic –like reactions have been reported. Vaccination for rabies, tetanus, arboviruses (EEEV/WEEV/WNV) may be considered if the area is considered endemic or increased risk factors are involved. Prior to vaccination, serologic screening for leptospirosis (multiple serovars), and WNV is recommended. Other vaccination regimens depend on regional requirements and exposure risk (consider multivalent vaccination for clostridial diseases).
VACCINATION OF TAPIRS

Dawn M. Zimmerman and Sonia Hernandez

Tapir immunization protocols and immunologic responses have not been thoroughly evaluated but have been adapted from similar species. Inactivated vaccines are often recommended to avoid the possibility of vaccine-induced disease. Vaccination against tetanus and other clostridial diseases are strongly recommended, particularly where domestic ungulates are present in the proximity of tapir enclosures. Equine encephalomyelitis virus (EEV) and WNV vaccination is recommended for endemic areas. Vaccination against infectious bovine rhinotracheitis is recommended for endemic areas and if the risk of infection from contact with domestic cattle is high. Rabies vaccination may be indicated. Encephalomyocarditis virus (EMCV) infection has been reported occasionally in zoos in warm climates, some resulting in deaths, but no vaccine is available; therefore, the main prevention is maintenance of appropriate hygiene, feeding practices and pest control.
Nondomestic suids and peccaries are susceptible to many of the same diseases as domestic swine and ungulates. These include leptospirosis, pasteurellosis, rabies, salmonellosis, and tuberculosis. Diagnosis and treatment are similar as for other species. A thorough review of infectious and parasitic disease was previously compiled and is presented in Tables 58-7 and 58-8.

Necrotizing enteritis caused by *Clostridium perfringens* was reported in collared peccaries and white-lipped peccaries from a facility in Brazil. Lethargy and inappetance were followed by death within 24 hours in seven animals. Crowded housing conditions were thought to have played a role in the disease outbreak. Feral swine have been a concern for the domestic swine industry because of the risk of disease transmission. Similarly, local feral swine may also act as a source of disease for exotic suids located in rural areas. Brucellosis was diagnosed in a group of red river hogs in a facility in Florida. Through testing of serum banked from the original institution and genotyping of the *Brucella* isolate, it was determined that local feral swine were the likely source of the infection (Janssen, personal communication, 2012).

Postweaning multisystemic wasting syndrome (PMWS) emerged in the domestic swine industry in the mid-1970s, and porcine Circovirus 2 (PCV2) was discovered to be associated with the syndrome. An illness in a 10-month-old red river hog in a facility in England fitted the criteria for PMWS. The hog died following a course of profuse diarrhea and weight loss. An enteropathogenic *Escherichia coli* and PCV2 were isolated from the hog. The source of the PCV2 was not identified.

In recent years, research has focused on influenza viruses. Domestic swine are of interest because of their ability for gene reassortment with the avian, human and swine influenza viruses. They may also be infected by various influenza viruses and the risk exists for influenza viruses to be transmitted among exotic swine species, their caretakers, and the visiting public.
Descriptions of infectious diseases in captive hippos consist mostly of individual case reports. Large disease outbreaks are restricted to the wild population. Anthrax (*Bacillus anthracis*) is the single most significant pathogen associated with high mortalities and periodic outbreaks in wild hippopotamus. Bacterial infections include tuberculosis, salmonellosis, and pasteurellosis and fatal E. coli septicemia and *Clostridium perfringens* type A infection have been reported in juvenile hippos. Several serotypes of *Salmonella* have been isolated from asymptomatic animals as well as animals with clinical signs such as lethargy, anorexia, or GI-colic. Beta-hemolytic and gamma-non-hemolytic streptococcal infections are the most common reported bacterial infections in captive animals, with a clinical spectrum ranging from frequently occurring skin infections resulting in severe dermatitis o rarer cases of vasculitis, osteomyelitis, placentitis, mastitis, or septicemia, sometimes resulting in fatalities. These skin infections are commonly associated with opportunistic co-infections by organisms such as *Morganella morganii*, *Klebsiella pneumonia*, *Citrobacter freundii*, *Enterococcus faecalis*, *Serratia liquefaciens*, and *Proteus vulgaris* and tend to persist but respond to aggressive antibiotic treatment with sulfametoxazole and trimetoprim, amoxicillin, pentoxifylline, cephalosporins. Furthermore, seasonally recurring dermatopathies, similar to *Streptococcus* infections have been reported, but these could not be attributed to a specific pathogen. Antibody titers to tetanus virus, *Brucella* and *Leptospira* have been reported in the wild common hippopotamus. *L. icterohaemorrhagiae* infection in a zoo animal led to a fatal outcome in a pigmy hippo. Antibodies to bovine herpesvirus 2 (BHV2), rinderpest virus, infectious bovine rhinotracheitis virus (IBR) and contagious bovine pleuropneumonia virus have been found in wild common hippos. A fatal
encephalomyocarditis virus (EMCV) infection in a pigmy hippo was reported in an Australian zoo.

PREVENTIVE MEDICINE
Immunizations vary with locality but should include protection against tetanus, leptospirosis, enterotoxemia type D and C and rabies.

Giraffidae
Chapter 61 page 609
Mads F. Bertelsen
PREVENTIVE MEDICINE
Routine vaccination is seldom performed, but vaccines against rabies, clostridial disease, and bluetongue, as well as rotavirus and coronavirus, are sometimes used.

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Tragulidae, Moschidae, and Cervidae
Chapter 62 Page 623
Nicholas J. Masters and Edmund Flach

PREVENTIVE MEDICINE
Vaccinations (e.g. multivalent clostridial vaccine) should be similarly based on knowledge of local disease risk and species susceptibility. However, unlike anthelmintic treatments, which may be given orally, (most efficiently if added to the concentrate pellet) vaccinations need to be injected by hand or dart, so good handling and restraint facilities are essential.

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PREVENTIVE MEDICINE
Well-designed preventive medicine protocols, including quarantine, regular disease screening, vaccination, sanitation and vermin control are important to the successful maintenance of nondomestic bovid collections. Annual vaccination for diseases of particular concern such as Clostridium species and rabies is commonly performed. Regional disease risk should be considered, as vaccination for some diseases following an outbreak may interrupt the disease cycle. Live vaccines should be used with caution in nondomestic ruminants.
VACCINATION

A variety of vaccines and vaccine protocols have been used in the Chilean flamingos (*Phoenicopterus chilensis*), red-tailed hawks (*Buteo jamacensis*) Andean condors (*Vultur gryphus*) and California condors (*Gymnogyps californicus*), great one-horned rhinoceros (*Rhinoceros unicornis*), sandhill cranes (*Grus Canadensis*), black-footed penguins (*Sphenicus demersus*), little blue penguins (*Eudyptula minor*), and American flamingos (*Phoenicopterus ruber*); Humboldt (*Sphenicus humboldti*) Magellanic (*Sphenicus magellanicus*), Gentoo (*Pygoscelis papua*), and Rockhopper penguins (*Eudypes chrysocome*), and Attwater prairie chickens (*Tympanuchus cupido*) with varying results. In a 2012 study in squirrel monkeys, a measles vaccine expressing the secreted form of WNV envelope glycoprotein induced protective immunity. A 2013 study in captive Nene geese (*Branta sandovicensis*) showed that a vaccine developed for human use (WN-80E) was highly immunogenic and had no adverse biologic effects. A recent paper provides excellent summaries of the current status of vaccine research (Recent progress in West Nile virus diagnosis and vaccination. Vet Res 43:16,2012). West Nile Encephalitis Virus Infection – Viral Pathogenesis and the Host Immune Response, edited by Michael S. Diamond, discusses available vaccines, as well as all other aspects of this important virus and must be consulted by anyone interested in WNV.