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# Information Resources on the Care and Welfare of Ferrets

AWIC Resource Series No. 38

December 2006

Updates [Information Resources on Ferrets, July 2002](#)

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## **INTRODUCTION**

This publication updates [Information Resources on Ferrets, 1991-2002](#) and involves a search multiple databases for the time period 2003–2006. The publication is broken into 26 different subject groups for easier searching and includes items for domestic ferrets (*Mustela putorius furo*) and black-footed ferrets (*Mustela nigripes*). Some of the references may be listed in more than one group depending on the topics addressed in the article. Selected Web sites are included in a separate chapter.

Domestic ferrets are commonly kept as pets in the United States and are often exhibited in zoos for public viewing. Ferrets are also used in many broad areas of research, including studies of cardiovascular disease, nutrition, respiratory diseases (such as SARS and human influenza), airway physiology, and gastrointestinal disease (such as peptic ulcers caused by *Helicobacter pylori*). Ferrets share many anatomical, metabolic and physiologic features with humans which has promoted their use as an animal model.

Ferrets as animals in research, teaching, testing, and exhibition are covered by the US Federal Animal Welfare Act. Standards for their housing and care are provided in [Subpart F](#) of the Animal Welfare Regulations -- Specifications for the Humane Handling, Care, Treatment, and Transportation of Warm-blooded Animals Other Than Dogs, Cats, Rabbits, Hamsters, Guinea Pigs, Nonhuman Primates, and Marine Mammals.

Black-footed ferrets are currently listed as endangered. In 1985, only 18 individual animals were known to exist in the wild. [Captive breeding and reintroduction programs](#) have led to the stabilization of black-footed ferret numbers, now estimated as more than 300 individuals in the wild. This resource contains a chapter exclusively devoted to black-footed ferret care and research. For additional information on the status of black-footed ferret populations and ongoing research, visit the [US Fish and Wildlife Species Profile: Black-footed ferret](#).

Each citation in the bibliography contains descriptor terms, an abstract when available, and the NAL call number if the particular source is available at the National Agricultural Library (NAL). Information on how to request materials that are included in the collection of the National Agricultural Library (NAL) may be found at:

<http://www.nal.usda.gov/services/request.shtml>.

Readers are cautioned as to the dynamic nature of the internet and the fact that Web addresses and content are subject to change. All sites are current as of December 2006.



*The Animal Welfare Information Center, Contact us: <http://www.nal.usda.gov/awic/contact.php>  
<http://www.nal.usda.gov/awic/pubs/Ferrets06/ferrets.htm>  
March 22, 2007*



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## Information Resources on the Care and Welfare of Ferrets

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### General

Antinoff, N. and K. Hahn (2004). **Ferret oncology: Diseases, diagnostics, and therapeutics.** *Veterinary Clinics of North America. Exotic Animal Practice* 7(3): 579-625, Vi. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Many standard diagnostic and chemotherapeutic protocols can be adapted for use in ferrets. Unique anatomic and clinical features dictate modification of protocols, but should not prohibit diagnosis or treatment. Ferrets may be the easiest of nontraditional species to treat with chemotherapeutics. We can provide more options for our patients, with improved quality of life and longer survival times than ever before. Although clients are never happy to hear the diagnosis of "cancer," it is no longer a word that condemns their beloved pet.

**Descriptors:** ferrets, neoplasms, diagnosis, diseases, oncology, chemotherapeutics.

Ball, R.S. (2002). **Husbandry and management of the domestic ferret.** *Lab Animal* 31(5): 37-42. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Descriptors:** ferrets, laboratory mammals, animal husbandry, animal welfare, odors, animal feeding, estrous cycle, estrus, ovulation, helicobacter, gastroenteritis, Aleutian disease, dirofilaria immitis, urinary calculi, urine pH, veterinary products, animal handling, induced ovulators.

Berzins, R., R. Helder, and T.H. Lode (2002). **The influence of odour familiarity on female polecat (*Mustela putorius*) mate choice.** *Ethology* 37: 23. ISSN: 0931-4202.

**Descriptors:** reproduction, behavior, mate choice, communication, housing, olfactory cues, female polecat, odor familiarity.

**Notes:** 4th International Symposium on Physiology and Behaviour of Wild and Zoo Animals, Berlin, Germany; September 29-October 02, 2002.

Bixler, H. and C. Ellis (2004). **Ferret care and husbandry.** *Veterinary Clinics of North America. Exotic Animal Practice* 7(2): 227-255, V. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Convivial and playful, the ferret has cohabited with humans for hundreds of years. Maintenance of this mustelid's health and quality of life is paramount for the endurance of the human-animal bond. This review article for veterinary care givers, veterinarians, and staff, encompasses discussions on: husbandry, clinical techniques, prevalent diseases, history taking, physical examination, vaccination, and pain recognition. This article also enables the veterinary community to contribute to the care and welfare of ferret patients by offering facts to distinguish these animals from dogs and cats.

**Descriptors:** animal husbandry, ferrets, care, welfare, clinical techniques, diseases, physical examination, vaccination, pain recognition.

Caley, P. and J. Hone (2005). **Assessing the host disease status of wildlife and the implications for disease control: *Mycobacterium bovis* infection in feral ferrets.** *Journal of Applied Ecology* 42(4): 708-719. ISSN: 0021-8901.

**NAL Call Number:** 410 J828

**Descriptors:** feral ferrets, disease status, disease control, assessing, implications, *Mycobacterium bovis*.

Carroll, E.E., R.R. Dubielzig, and R.D. Schultz (2002). **Cats differ from mink and ferrets in their response to commercial vaccines: A histologic comparison of early vaccine reactions.** *Veterinary Pathology* 39(2): 216-227. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Early histologic changes in lesions at vaccine sites were compared in cats, mink, and ferrets. Twenty-four 4-month-old cats, 20 4-month-old mink, and 20 12-month-old ferrets were vaccinated with three rabies virus vaccines, two feline leukemia virus vaccines, alum adjuvant, and saline. Injection sites were excised at selected time points up to 21 days postvaccination. Histologic examination of the tissue revealed significant differences among the cats, mink, and ferrets in the local response to the commercial vaccines. When compared with ferrets and mink, cats had more lymphocytes in response to all three rabies vaccines. Production of fibroblasts, collagen, and macrophages differed among the three killed aluminum-adsorbed vaccines in cats but did not differ significantly in mink or ferrets. Cats produced fewer binucleate cells than did mink or ferrets in response to the two adjuvanted leukemia virus vaccines. Differences seen in early tissue response of cats to commercial vaccines may be related to the increased predisposition of cats to vaccine-associated sarcomas.

**Descriptors:** cats, ferrets, leukemia virus, mink, rabies vaccines, viral vaccines, skin immunology, vaccine sites, lesions.

Castillo, a.B., L.N. Metz, and R.B. Martin (2003). **The effects of ovariectomy on intracortical remodeling in the female ferret (*Mustela furo*): A pilot study.** *Journal of Musculoskeletal & Neuronal Interactions* 3(4): 418-420. ISSN: 1108-7161.

**Descriptors:** female ferret, ovariectomy, intracortical remodeling, meeting, pilot study, endocrine system.

**Notes:** Thirty-third International Sun Valley Hard Tissue Workshop, Sun Valley, ID, USA; August 03-07, 2003.

Chitty, J.R. (2004). **Export/import of ferrets under the Pet Travel Scheme.** *Veterinary Record* 155(6): 183. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Descriptors:** ferrets, quarantine, travel, Great Britain, quarantine standards, vaccination, export, import.

Christensson, M. and M. Garwicz (2005). **Time course of postnatal motor development in ferrets: Ontogenetic and comparative perspectives.** *Behavioural Brain Research* 158(2): 231-242. ISSN: 0166-4328.

**Descriptors:** ferrets, postnatal motor development, motor behavior, rats, experimental animals, comparative study.

Cloe, A., S. Woodley, P. Waters, H. Zhou, and M. Baum (2004). **Contribution of anal scent gland and urinary odorants to mate recognition in the ferret.** *Physiology & Behavior* 82(5): 871-875. ISSN: 0031-9384.

**Descriptors:** *Mustela putorius furo*, olfactory signals, ferrets, anal scent glands, mating partner preference, urinary odorants, estradiol benzoate, testosterone propionate, scent gland odorants, sex discrimination.

Cooper, J.E. (2002). **The ferret, and other small mammals--a European veterinarian's perspective.** *Proceedings of the North American Veterinary Conference* 16: 9-10.

**NAL Call Number:** SF605.N672

**Descriptors:** ferrets, small mammals, rodents, rabbits, veterinary services, Europe.

**Notes:** In the volume: Veterinary technicians & practice managers. Part of a three volume set. Meeting held January 12-16, 2002 in Orlando, Florida.

Crawford, R.L., J. D'Anna and T. Allen (Animal Welfare Information Center (U.S.)) (2002). **Information Resources on Ferrets: September 1991-July 2002.**, The Dept.: Beltsville, Md.,

**Online:** <http://www.nal.usda.gov/awic/pubs/ferrets/ferrets.htm>

**NAL Call Number:** aQL737.C25 C73 2003

**Descriptors:** ferrets as laboratory animals, bibliography, animal pathogens, animal well-being, animal welfare, animal behavior, circulatory system, animal physiology, digestive system, anatomy, biology, nutrition, reproduction.

**Notes:** Updates *Ferrets as Laboratory Animals: a bibliography, September 1991.*

Czub, M., H. Weingartl, S. Czub, R. He, and J. Cao (2005). **Evaluation of modified vaccinia virus Ankara based recombinant SARS vaccine in ferrets.** *Vaccine* 23(17-18): 2273-2279. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Severe acute respiratory syndrome (SARS) caused by a newly identified coronavirus (SARS-CoV) remains a threat to cause epidemics as evidenced by recent sporadic cases in China. In this communication, we evaluated the efficacy and safety of two SARS vaccine candidates based on the recombinant modified vaccinia Ankara (MVA) expressing SARS-CoV spike or nucleocapsid proteins in ferrets. No clinical signs were observed in all the ferrets challenged with SARS-CoV. On the other hand, vaccination did not prevent SARS-CoV infection in ferrets. In contrast, immunized ferrets (particularly those immunized with rMVA-spike) exhibited significantly stronger inflammatory responses and focal necrosis in liver tissue after SARS-CoV challenge than control animals. Thus, our data suggest that enhanced hepatitis is linked to vaccination with rMVA expressing SARS-CoV antigens.

**Descriptors:** ferrets, sars virus, viral vaccines, viral antigens, hepatitis, immunology, RNA, viral analysis, severe acute respiratory syndrome.

de Lisle, G.W., G.F. Yates, P. Caley, and R.J. Corboy (2005). **Surveillance of wildlife for *Mycobacterium bovis* infection using culture of pooled tissue samples from ferrets (*Mustela furo*).** *New Zealand Veterinary Journal* 53(1): 14-18. ISSN: 0048-0169.

**Abstract:** AIM: To compare culture results of homogenates of pooled lymph nodes from individual ferrets with and without macroscopic lesions of bovine tuberculosis for the presence of *Mycobacterium bovis*, and to determine whether homogenates from 10-30 ferrets could be combined and cultured without loss of sensitivity as a possible method for improving cost-effectiveness of surveillance for *M. bovis* infection in wildlife populations. METHODS: Numbers of colony forming units (cfu) of *M. bovis* present in cultures of homogenates of pooled lymph nodes from individual ferrets known to be infected and having no visible lesions (NVL) or macroscopic lesions consistent with bovine tuberculosis were determined. Prevalences of *M. bovis* infection in populations of ferrets in the Marlborough region of the South Island of New Zealand were determined by culturing homogenates of pooled lymph nodes from individual animals. Samples from homogenates from North Canterbury were combined to form pools representing 10, 20 and 30 animals and also cultured for *M. bovis*. RESULTS: Fewer *M. bovis* cfu were isolated from ferrets with NVL (mean=0.77 log<sub>10</sub>) compared with ferrets with macroscopic lesions (mean=3.22 log<sub>10</sub>; p<0.05). The mean prevalence of infection in eight different surveys involving 427 ferrets from the Marlborough region was 18% (range 8-44%), which included a small number of animals with macroscopic lesions of tuberculosis. Pooling of samples from up to 30 different ferrets with NVL did not reduce the sensitivity of detecting *M. bovis* infected populations. CONCLUSION: Culturing of pools of lymph node samples detected a significant proportion of *M. bovis*-infected ferrets that would otherwise have gone unnoticed based on samples that had only macroscopic lesions. Culturing of samples pooled from up to 30 different ferrets could provide significant cost savings in surveys of wildlife for the presence of *M. bovis* infection without any apparent loss of sensitivity.

**Descriptors:** bacteriological techniques, ferrets, *Mycobacterium bovis*, tuberculosis, wild animals, New Zealand, population surveillance, predictive value of tests.

Dunayer, E. (2004). **Ibuprofen toxicosis in dogs, cats, and ferrets.** *Exotic DVM* 99(7): 580 582, 584, 586. ISSN: 8750-7943.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, dogs, cats, ibuprofen, toxicosis.

Fan, J., X. Liang, M.S. Horton, H.C. Perry, M.P. Citron, G.J. Heidecker, T.M. Fu, J. Joyce, C.T. Przysiecki, P.M. Keller, V.M. Garsky, R. Ionescu, Y. Rippeon, L. Shi, M.A. Chastain, J.H. Condra, M.E. Davies, J. Liao, E.A. Emini, and J.W. Shiver (2004). **Preclinical study of influenza virus A M2 peptide conjugate vaccines in mice, ferrets, and rhesus monkeys.** *Vaccine* 22(23-24): 2993-3003. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** A universal influenza virus vaccine that does not require frequent updates and/or annual immunizations will offer significant advantages over current seasonal flu vaccines. The highly conserved

influenza virus A M2 membrane protein has been previously suggested as a potential antigen target for such a vaccine. Here, we report systematic evaluation of M2 peptide conjugate vaccines (synthetic peptides of M2 extracellular domain conjugated to keyhole limpet hemocyanin (KLH) or *Neisseria meningitidis* outer membrane protein complex (OMPC)) in mice, ferrets, and rhesus monkeys. The conjugate vaccines were highly immunogenic in all species tested and were able to confer both protection against lethal challenge of either H1N1 or H3N1 virus in mice and reduce viral shedding in the lower respiratory tracts of mice and ferrets. The protection against lethal challenge in mice could also be achieved by passive transfer of monkey sera containing high M2 antibody titers. In addition, we showed that M2 antisera were cross reactive with M2 peptides derived from a wide range of human influenza A strains, but they failed to react with M2 peptides of the pathogenic H5N1 virus (A/Hong Kong/97). The data presented here will permit better understanding of the potential of an M2-based vaccine approach.

**Descriptors:** ferrets, mice, rhesus, influenza A virus, influenza vaccines, orthomyxoviridae infections, antibodies, lung virology, *Macaca mulatta*, inbred Balb C mice, nasal mucosa virology, *neisseria meningitidis*, conjugate vaccines, virus replication.

Garipis, N. and K.P. Hoffmann (2003). **Visual field defects in albino ferrets (*Mustela putorius furo*)**. *Vision Research* 43(7): 793-800. ISSN: 0042-6989.

**Abstract:** The extent of the horizontal visual field was determined behaviourally in 4 pigmented and 5 albino ferrets (*Mustela putorius furo*, Carnivora, Mammalia) using perimetry. During binocular vision, all pigmented and three albino ferrets responded equally well to stimuli presented anywhere along the horizontal perimeter in the central 180 degrees of the visual field. The remaining two albinos had a visual field defect in the right hemifield (>30 degrees eccentricity). During monocular vision, a significant difference between the visual fields of pigmented and albino ferrets became apparent. In pigmented ferrets, the visual field of each eye included the ipsilateral (temporal) and a substantial portion of the contralateral (nasal) hemifield. In albinos, the visual field of each eye was limited to the ipsilateral hemifield and reactions to visual stimuli abruptly declined directly beyond the vertical meridian.

**Descriptors:** ferrets, albinism, vision disorders, perimetry methods, albino ferrets, visual field.

Greenacre, C.B. (2003). **Incidence of adverse events in ferrets vaccinated with distemper or rabies vaccine: 143 cases (1995-2001)**. *Journal of the American Veterinary Medical Association* 223(5): 663-665. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** **OBJECTIVE:** To determine the incidence of adverse events in ferrets vaccinated with a modified-live avian cell culture canine distemper virus vaccine licensed for use in ferrets, an inactivated rabies vaccine licensed for use in ferrets, or both. **DESIGN:** Retrospective study. **ANIMALS:** 143 ferrets. **PROCEDURE:** Medical records were reviewed to identify ferrets that had an adverse event after vaccination. **RESULTS:** Adverse events developed within 25 minutes after vaccination in 13 ferrets. One ferret developed an adverse event after receiving a distemper and a rabies vaccine simultaneously and developed a second adverse event the following year after receiving the rabies vaccine alone. Therefore, a total of 14 adverse events were identified. All adverse events were an anaphylactic reaction characterized by generalized hyperemia, hypersalivation, and vomiting. Ten of the 14 anaphylactic reactions occurred after ferrets received both vaccines, 3 occurred after ferrets received the distemper vaccine alone, and 1 occurred after a ferret received the rabies vaccine alone. Incidences of adverse events after administration of both vaccines, the distemper vaccine alone, and the rabies vaccine alone were 5.6, 5.9, and 5.6%, respectively. Ferrets that had an anaphylactic reaction were significantly older at the time of vaccination than were ferrets that did not. **CONCLUSIONS AND CLINICAL RELEVANCE:** Results suggest that there may be a high incidence of anaphylactic reactions after vaccination of domestic ferrets. Ferrets should be observed for at least 25 minutes after vaccination, and veterinarians who vaccinate ferrets should be prepared to treat anaphylactic reactions.

**Descriptors:** ferrets, distemper virus, canine immunology, rabies vaccines, adverse effects of viral vaccines, age factors, anaphylaxis, incidence of rabies virus, retrospective studies, risk factors.

**Notes:** Comments: Comment In: J Am Vet Med Assoc. 2003 Oct 15;223(8):1112; author reply 1112.

He, T., H. Friede, and S. Kiliaridis (2002). **Dental eruption and exfoliation chronology in the ferret (*Mustela putorius furo*)**. *Archives of Oral Biology* 47(8): 619-623. ISSN: 0003-9969.

**NAL Call Number:** RK1.A6989

**Abstract:** Substituting ferrets for rats and dogs as animal models for craniofacial research is favourable because of the similarity of many of the ferret's anatomical, metabolic and physiological features to those of man. Other advantages are cost-effectiveness and possibly less ethical controversy. However, information on the dental chronology of ferrets needs to be supplemented if this animal is to be promoted as an alternative model. Dental development was here examined in 16 ferrets (eight males, eight females) from three litters at between 12 and 90 days of age. Dental eruption and exfoliation were assessed and recorded every second day. The sequence of eruption of deciduous and permanent teeth was determined and data were analysed statistically. Also, any sex-related differences in eruption and exfoliation ages were defined. No deciduous incisors were observed to erupt in this group of animals. Other deciduous teeth erupted between the 19th and 31st postnatal days, and exfoliated between days 51 and 76. The time of eruption of the permanent teeth ranged from 42 to 77 days, in accordance with the stage of the mixed dentition. The female ferrets were generally ahead of the males in the exfoliation age of their deciduous teeth and the eruption age of their permanent teeth, but this, a sex difference did not apply to the eruption age of the deciduous teeth. These extended basic data might facilitate the introduction of this alternative experimental animal into craniofacial research.

**Descriptors:** ferrets physiology, animal models, tooth eruption physiology, tooth exfoliation, deciduous teeth, aging physiology, sex factors.

Hoefler, H.L. (2004). **The biology and husbandry of the pet ferret.** In: *Small animal and exotics Book two: Pain management zoonosis Proceedings of the North American Veterinary Conference., January 17, 2004-January 21, 2004, Orlando, Florida, USA.,* Eastern States Veterinary Association: Gainesville, USA, Vol. 18, p. 1383-1384.

**Descriptors:** ferrets, behavior, housing, husbandry, nutrition, clinical examination, diet, Mustela.

Hoffmann, K.P., N. Garipis, and C. Distler (2004). **Optokinetic deficits in albino ferrets (*Mustela putorius furo*): A behavioral and electrophysiological study.** *Journal of Neuroscience* 24(16): 4061-4069. ISSN: 1529-2401.

**Abstract:** We compared the horizontal optokinetic reaction (OKR) and response properties of retinal slip neurons in the nucleus of the optic tract and dorsal terminal nucleus (NOT-DTN) of albino and wild-type ferrets (*Mustela putorius furo*). In contrast to pigmented ferrets, we were unable to observe OKR in albino ferrets during binocular and monocular viewing using random dot full field stimulation and electro-oculography (EOG). Observations during early postnatal life indicate that regular OKR is present in pigmented pups 3 d after eye opening but is absent at any stage during development in albino ferrets. Unilateral muscimol injections to inactivate all neurons in the NOT-DTN containing GABA(A) and GABA(C) receptors caused spontaneous horizontal nystagmus with slow phases away from the injected hemisphere in albino as well as in pigmented animals. Retinal slip neurons in the NOT-DTN of albino ferrets identified by antidromic activation from the inferior olive and orthodromic activation from the optic chiasm were well responding to intermittent bright light stimuli, but many showed a profound reduction of responsiveness to moving stimuli. The movement-sensitive neurons exhibited no clear direction selectivity for ipsiversive stimulus movement, a characteristic property of these neurons in pigmented ferrets and other mammals. Thus, the defect rendering albino ferrets optokinetically nonresponsive is located in the visual pathway subserving the OKR, namely in or before the NOT-DTN, and not in oculomotor centers.

**Descriptors:** ferrets, albinism, physiopathology, eye movements, motion perception, visual pathways, behavior, electrooculography, electrophysiology, nystagmus, olivary nucleus, optic chiasm, photic stimulation.

Huber, V.C. and J.A. McCullers (2006). **Live attenuated influenza vaccine is safe and immunogenic in immunocompromised ferrets.** *Journal of Infectious Diseases* 193(5): 677-684. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** Patients undergoing chemotherapy for cancer are highly susceptible to influenza virus infection. Prevention of influenza virus infection is complicated in the immunocompromised host because of suboptimal responses to the trivalent inactivated influenza vaccine (TIV). A new, live attenuated influenza vaccine (LAIV; FluMist) may offer a more effective alternative to TIV, but the safety of this LAIV in immunocompromised patients must first be established. In the present study, FluMist was administered to ferrets immunocompromised by treatment with dexamethasone and cytarabine. Ferrets exhibited no signs or symptoms attributable to FluMist, and nasal clearance of LAIV strains from immunocompromised ferrets was similar to

that from control ferrets. Serum antibody responses against the vaccinating strains were analyzed as a measure of vaccine efficacy. Antibody titers to all 3 vaccine strains in immunocompromised ferrets were similar to those seen in mock-treated control ferrets, as assessed by microneutralization assay. These findings support the potential use of this vaccine in immunocompromised humans.

**Descriptors:** ferrets, blood antibodies, immunocompromised host, influenza A virus, influenza B virus, influenza vaccines, cytarabine, dexamethasone, immunosuppressive agents.

Johnson Delaney, C.A. (2005). **Ferret cardiopulmonary resuscitation.** *Seminars in Avian and Exotic Pet Medicine* 14(2): 135-142. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, cardiopulmonary resuscitation, therapy, heart diseases, reviews, techniques, cardiac massage, cardiac arrest.

Kona Boun, J.J., B. Mercier, E. Troncy, J. Pare, and I. Langlois (2004). **Le furet domestique. [The domestic ferret].** *Medecin Veterinaire Du Quebec* 34(3): 220-227.

**Descriptors:** ferrets, anesthetic techniques, handling, venous access, catheterization, intubation, analgesics, anesthetics, fluid administration.

**Language of Text:** French.

Kottwitz, J. (2004). **Horizontal beam radiography in ferrets.** *Exotic DVM* 6(1): 37-41. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, horizontal beam radiography, diagnostic techniques, restraint.

Land, B. (2003). *The Simple Guide to Ferrets.*, T.F.H. Publications: Neptune City, NJ, 201 p. ISBN: 0793821169.

**NAL Call Number:** SF459.F47 L36 2003

**Descriptors:** ferrets, pet animals.

Lewington, J.H. (2005). **Ferret fanatic.** *Australian Veterinary Journal* 83(1-2): 29. ISSN: 0005-0423.

**NAL Call Number:** 41.8 Au72

**Descriptors:** animal husbandry, ferrets, welfare.

Lorigan, R.D. (2002). **The use of deer, pigs, and ferrets as indicator species for detecting TB.** *Proceedings - Vertebrate Pest Conference* 20: 249-252. ISSN: 0507-6773.

**Descriptors:** Cervidae, *Sus scrofa*, *Mustela furo*, bacterial diseases, feral populations as indicators for pathogen detection, transmission of bacteria, tuberculosis, *Mycobacterium bovis*, New Zealand.

Moore, G.E., N.W. Glickman, M.P. Ward, K.S. Engler, H.B. Lewis, and L.T. Glickman (2005). **Incidence of and risk factors for adverse events associated with distemper and rabies vaccine administration in ferrets.** *Journal of the American Veterinary Medical Association* 226(6): 909-912. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** OBJECTIVE: To determine incidence of and risk factors for adverse events associated with distemper and rabies vaccine administration in ferrets. DESIGN: Retrospective cohort study. ANIMALS: 3,587 ferrets that received a rabies or distemper vaccine between January 1, 2002, and December 31, 2003. PROCEDURES: Electronic medical records were searched for possible vaccine-associated adverse events. Adverse events were classified by attending veterinarians as nonspecific vaccine reactions, allergic reactions, or anaphylaxis. Patient information that was collected included age, weight, sex, cumulative number of distemper and rabies vaccinations received, clinical signs, and treatment. The association between potential risk factors and occurrence of an adverse event was estimated with logistic regression. RESULTS: 30 adverse events were recorded. The adverse event incidence rates for administration of rabies vaccine alone, distemper vaccine alone, and rabies and distemper vaccines together were 0.51%, 1.00%, and 0.85%, respectively. These rates were not significantly different. All adverse events occurred immediately following vaccine administration and most commonly consisted of vomiting and diarrhea (52%) or vomiting alone (31%). Age, sex, and body weight were not significantly associated with occurrence of adverse events, but adverse event incidence rate increased as the cumulative number of distemper or rabies vaccinations received increased. In multivariate logistic regression

analysis, only the cumulative number of distemper vaccinations received was significantly associated with the occurrence of an adverse event. **CONCLUSIONS AND CLINICAL RELEVANCE:** Results suggest that in ferrets, the risk of vaccine-associated adverse events was primarily associated with an increase in the number of distemper vaccinations.

**Descriptors:** diarrhea, ferrets, rabies vaccines, adverse effects of viral vaccines, distemper virus, canine immunology, logistic models, rabies virus, vomiting.

Nugent, J.S., B. Whisman, and L.L. Hagan (2003). **Ferret allergy: Identification of serum specific ige to albumin with crossreactivity to cat.** *Journal of Allergy and Clinical Immunology* 111(2 Abstract Supplement): S324. ISSN: 0091-6749.

**Descriptors:** ferret, allergy, immune system disease, serum specific ige, albumin, electrophoretic techniques, cats.

**Notes:** AAAAI 60th Anniversary Meeting, Denver, CO, USA; March 7-12, 2003.

Oglesbee, B.L. (2006). *The 5-Minute Veterinary Consult: Ferret and Rabbit.*, 1st edition, Blackwell Publishing: Ames, Iowa, 422 p. ISBN: 0781793998.

**NAL Call Number:** SF997.5.F47 O35 2006

**Descriptors:** ferrets, rabbits, diseases, handbooks, veterinary medicine.

Philipp, R., C. Distler, and K.P. Hoffmann (2006). **A motion-sensitive area in ferret extrastriate visual cortex: An analysis in pigmented and albino animals.** *Cerebral Cortex* 16(6): 779-790. ISSN: 1047-3211.

**Abstract:** In search of the neuronal substrate for motion analysis in the ferret (*Mustela putorius furo*), we extracellularly recorded from extrastriate visual cortex in five pigmented and two albino ferrets under general anaesthesia and paralysis. Visual stimulation consisted of large area random dot patterns moving either on a circular path in the frontoparallel plane or expanding and contracting radially. Strongly direction-selective neurons were recorded in a circumscribed area in and just posterior to the suprasylvian sulcus, thus named by us the posterior suprasylvian area (area PSS). Altogether, we recorded 210 (90%) and 95 (72%) PSS neurons in pigmented and albino ferrets, respectively, that were direction selective. In these neurons responses during random dot pattern stimulation in the preferred direction were at least twice as strong than stimulation in the non-preferred direction. Response strength in preferred direction and tuning sharpness of PSS neurons in albinos were significantly reduced when compared to pigmented animals (median values: 34.1 versus 14.8 spikes/s and 142 versus 165 degrees for pigmented and albino ferrets, respectively). Inter-spike-intervals during visual stimulation were significantly shorter in pigmented (median 9 ms) than in albino PSS neurons (median 14 ms). Our data indicate that area PSS may play a crucial role in motion perception in the ferret.

**Descriptors:** ferrets, albinism, ocular physiopathology, motion perception, nerve net, visual cortex, evoked potentials, photic stimulation, pigmentation.

Platt, S.R., P.M. Dennis, and L.J. McSherry (2004). **Composition of cerebrospinal fluid in clinically normal adult ferrets.** *American Journal of Veterinary Research*: 758-760. ISSN: 0002-9645.

**NAL Call Number:** 41.8 Am3A

**Abstract:** Objective--To determine the protein and cellular composition of CSF in healthy adult ferrets. Animals--42 clinically normal adult ferrets. Procedure--CSF samples were collected from the cerebellomedullary cistern of anesthetized ferrets by use of disposable 25-gauge, 1.6-cm-long hypodermic needles. Samples were processed within 20 minutes after collection. The number of WBCs and RBCs per microliter of CSF was counted by use of a hemacytometer. The total protein concentration was determined by use of an automated chemistry analyzer. Results--Total WBC counts (range, 0 to 8 cells/mL; mean, 1.59 cells/mL) in CSF of ferrets were similar to reference range values obtained for CSF from other species. Twenty-seven CSF samples had < 100 RBCs/mL (mean, 20.3 RBCs/mL). A small but significant effect of blood contamination on WBC counts was found between the 27 CSF samples with < 100 RBCs/mL and the remaining samples. Protein concentrations in CSF of ferrets (range, 28.0 to 68.0 mg/dL; mean, 31.4 mg/dL) were higher than has been reported for the CSF of dogs and cats. A significant effect of blood contamination on the CSF protein concentration was not found. Conclusion and Clinical Relevance--We have established reference range values for WBC counts and protein concentrations in CSF from healthy adult ferrets that may be useful in the clinical investigation of CNS disease. Results of our study indicate that the WBC count is significantly affected

by blood contamination of the CSF sample. Reprinted by permission of the publisher.

**Descriptors:** normal ferrets, adult, cerebral spinal fluid, anesthesia, white blood cell counts.

Reinhardt, V. and A. Reinhardt (2006). *Database on Refinement of Housing and Handling Conditions and Environmental Enrichment for Animals Kept in Laboratories: Rodents, Rabbits, Cats, Dogs, Ferrets, Farm Animals, Horses, Birds Fishes, Amphibians and Reptiles.*, [Online Database]

**Online:** <http://labanimals.awionline.org/SearchResultsSite/refine.aspx>

**NAL Call Number:** SF406.3

**Descriptors:** laboratory animals housing databases, laboratory animals environmental enrichment databases, databases, enrichment, housing.

Schoemaker, N.J. (2002). **Ferrets.** In: A. Meredith and S. Redrobe (Editors), *BSAVA Manual of Exotic Pets*, 4th edition, British Small Animal Veterinary Association: Quedgeley, UK, p. 93-101. ISBN: 0905214471.

**Descriptors:** ferrets, anesthesia, analgesics, housing, biology, diseases, diagnostic techniques, diet, drug therapy, euthanasia, handling, parasites, surgery.

Spurr, E., J. Ragg, C. O'Connor, W. Hamilton, H. Moller, A. Woolhouse, C. Morse, G. Morriss, G. Arnold, and B. Clapperton (2004). **Effect of concentration of anal gland scent lures on the capture rate of ferrets (*Mustela furo*) in winter and spring.** *New Zealand Journal of Zoology* 31(3): 227-232. ISSN: 0301-4223.

**NAL Call Number:** QL1.A1N4

**Descriptors:** *Mustela furo*, scent lures, anal gland secretions, capture rate evaluation, attractants for feral ferrets, seasonal variations, South Island of New Zealand.

Willard, T.R. (2002). **Ferrets.** *Exotic DVM* 4(4): 36-37. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, anatomy, physiology, diets, feed formulation, nutrient requirements.

Wise, A.G., M. Kiupel, C. Isenhour, and R. Maes (2003). **Development and evaluation of molecular techniques for the diagnosis of Epizootic Catarrhal Enteritis infection of ferrets.** In: *Erkrankungen der Zootiere: Verhandlungsbericht des 41 Internationalen Symposiums uber die Erkrankungen der Zoo und Wildtiere. [Proceedings of the Institute for Zoo and Wildlife Research, Berlin, No.5], May 28, 2003-June 1, 2003, Rome, Italy*, 427-431 p.

**Descriptors:** ferrets, epizootic catarrhal enteritis, coronavirus, etiology, diagnosis, diagnostic techniques, development, feces, RNA, saliva, viral diseases.

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### Anatomy

Bizley, J.K., I. Nelken, F.R. Nodal, B. Ahmed, A.J. King, and J.W.H. Schnupp (2002). **An investigation into the functional anatomy of ferret auditory cortex using optical imaging and multi - electrode recordings.** In: *32nd Annual Meeting of the Society for Neuroscience, Society for Neuroscience Abstract Viewer and Itinerary Planner., November 2, 2002-November 7, 2002, Orlando, Florida, USA., Vol. 2002, p. Abstract No. 354.10.*

**Descriptors:** auditory cortex, functional anatomy, ferret, optical imaging, area mapping, recordings, auditory stimuli, frequency tuning.

Christensson, M. and M. Garwicz (2005). **Time course of postnatal motor development in ferrets: Ontogenetic and comparative perspectives.** *Behavioural Brain Research* 158(2): 231-242. ISSN: 0166-4328.

**Descriptors:** ferrets, postnatal motor development, motor behavior, rats, experimental animals, comparative study.

He, T., H. Friede, and S. Kiliaridis (2002). **Macroscopic and roentgenographic anatomy of the skull of the ferret (*Mustela putorius furo*).** *Laboratory Animals* 36(1): 86-96. ISSN: 0023-6772.

**NAL Call Number:** QL55.A1L3

**Abstract:** Normal macroscopic and roentgenographic features of the skull of the ferret (*Mustela putorius furo*) were examined and described. Data were based on a sample of 100 (50 male and 50 female) adult ferrets of known body weight and age. The skull was described macroscopically according to six standard views, i.e. dorsal, lateral, ventral, caudal, cranial and midsagittal. The mandible was described separately. The roentgenographic characteristics of the ferret skull were demonstrated only in lateral and dorsoventral projections. Furthermore, the skull length and width as well as the minimum frontal width were measured, and skull indices were derived from relevant measurements. Sexual dimorphism was examined both morphologically and craniometrically. Besides the common features of a carnivore skull, the ferret skull is relatively elongated and flat with a short facial region. The skulls of adult male ferrets are about 17% longer and 22% wider than those of the females. Significant sexual dimorphism also exists regarding certain skull indices. The general features and some dimensional parameters of the adult ferret skull support the contention that the ferret would be an interesting and workable alternative animal model in craniofacial research.

**Descriptors:** ferrets anatomy, histology, radiography, skull anatomy, histology, skull radiography, random allocation, sex characteristics.

He, T. and S. Kiliaridis (2004). **Craniofacial growth in the ferret (*Mustela putorius furo*)--a cephalometric study.** *Archives of Oral Biology* 49(10): 837-848. ISSN: 0003-9969.

**NAL Call Number:** RK1.A6989

**Abstract:** OBJECTIVE: When suggesting the ferret as a valid laboratory model in craniofacial research, it is essential to know about its normal craniofacial growth. DESIGN: Sixteen ferret kits (eight male and eight female) were selected for the present investigation. Serial lateral and dorsoventral cephalograms were taken on each animal at a mean age of 25, 35, 55, 80 and 300 days. The cephalograms were then digitised and the coordinates of 33 landmarks were derived on each set of cephalograms. Thirty-four variables were then

calculated on each set of cephalograms by computer image programs with the coordinate data. Results were analysed statistically, and the craniofacial growth pattern and related sexual dimorphism were described in three perspectives: lateral and dorsoventral viscerocranium and neurocranium, and lateral mandible. **FINDINGS:** In both sexes, the viscerocranium and neurocranium follow an orderly pattern of expansive growth in three dimensions. The growth of the mandible is mainly characterised by an anteroposterior elongation of the mandibular body, an enlargement of the coronoid process, and an increase in height of the alveolar process. The growth rate varies with site. Craniofacial growth in ferrets starts to slow down and finally ceases earlier in female than in male animals.

**Descriptors:** ferrets, craniofacial growth, maxillofacial development, physiology, skull growth and development, cephalometry, mandible growth, sex factors, skull radiography.

He, T. and S. Kiliaridis (2003). **Effects of masticatory muscle function on craniofacial morphology in growing ferrets (*Mustela putorius furo*)**. *European Journal of Oral Sciences* 111(6): 510-517. ISSN: 0909-8836.

**Abstract:** Studying the effects of masticatory muscle function on craniofacial morphology in animal models with different masticatory systems is important for further understanding of related issues in humans. Forty 5-wk-old male ferrets were equally divided into two groups. One group was fed a diet of hard pellets (HDG) and the other group was fed the same diet but softened with water (SDG). Lateral and dorsoventral cephalograms were taken on each group after 6 months. Cephalometric measurements were performed by digital procedures. For SDG ferrets, the hard palate plane was more distant from the cranial base plane, and canines were more proclined compared with HDG ferrets. The SDG ferrets were also found to have smaller interfrontal and interparietal widths, and a slenderer zygomatic arch than the HDG ferrets. In the mandible, the coronoid process was generally shorter and narrower for the SDG ferrets. The effects of the altered masticatory muscle function on craniofacial morphology in growing ferrets seemed to differ from those previously reported in other animal models studied under similar experimental conditions. Such differences in the effects are presumably related to the differences in the mode of mastication, craniofacial anatomy and growth pattern in different animal models.

**Descriptors:** ferret growth and development, mastication, masticatory muscles, maxillofacial development, skull growth and development, feed, nutrition, facial bones, mandible.

Hoffmann, K.P., N. Garipis, and C. Distler (2004). **Optokinetic deficits in albino ferrets (*Mustela putorius furo*): A behavioral and electrophysiological study**. *Journal of Neuroscience* 24(16): 4061-4069. ISSN: 1529-2401.

**Abstract:** We compared the horizontal optokinetic reaction (OKR) and response properties of retinal slip neurons in the nucleus of the optic tract and dorsal terminal nucleus (NOT-DTN) of albino and wild-type ferrets (*Mustela putorius furo*). In contrast to pigmented ferrets, we were unable to observe OKR in albino ferrets during binocular and monocular viewing using random dot full field stimulation and electro-oculography (EOG). Observations during early postnatal life indicate that regular OKR is present in pigmented pups 3 d after eye opening but is absent at any stage during development in albino ferrets. Unilateral muscimol injections to inactivate all neurons in the NOT-DTN containing GABA(A) and GABA(C) receptors caused spontaneous horizontal nystagmus with slow phases away from the injected hemisphere in albino as well as in pigmented animals. Retinal slip neurons in the NOT-DTN of albino ferrets identified by antidromic activation from the inferior olive and orthodromic activation from the optic chiasm were well responding to intermittent bright light stimuli, but many showed a profound reduction of responsiveness to moving stimuli. The movement-sensitive neurons exhibited no clear direction selectivity for ipsiversive stimulus movement, a characteristic property of these neurons in pigmented ferrets and other mammals. Thus, the defect rendering albino ferrets optokinetically nonresponsive is located in the visual pathway subserving the OKR, namely in or before the NOT-DTN, and not in oculomotor centers.

**Descriptors:** ferrets, albinism, physiopathology, eye movements, motion perception, visual pathways, behavior, electrooculography, electrophysiology, nystagmus, olivary nucleus, optic chiasm, photic stimulation.

Johnson Delaney, C.A. (2005). **The ferret gastrointestinal tract and *Helicobacter mustelae* infection**. *Veterinary Clinics of North America. Exotic Animal Practice* 8(2): 197-212. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Descriptors:** ferrets, microbiology, gastrointestinal tract, helicobacter infections, *Helicobacter mustelae* pathogenicity, biliary tract, disease models, pancreas, exocrine physiology.

Takemura, A., I. Toda, H. Ike, M. Uemura, Y. Tamaada, and F. Suwa (2004). **SEM studies of the lingual papillae in the ferret (*Mustela putorius furo*)**. *Anatomical Science International* 79(August): 404. ISSN: 1447-6959.

**Descriptors:** ferret, lingual papillae, dental system, ingestion, imaging, microscopy techniques.

**Notes:** 16th International Congress of the IFAA (International Federation of Associations of Anatomists) and the 109th Annual Meeting of the Japanese Association of Anatomists, Kyoto, Japan; August 22-27, 2004.

Triantafyllou, A., D. Fletcher, and J. Scott (2005). **Organic secretory products, adaptive responses and innervation in the parotid gland of ferret: A histochemical study**. *Archives of Oral Biology* 50(9): 769-777. ISSN: 0003-9969.

**NAL Call Number:** RK1.A6989

**Abstract:** To qualify cellular events of possible pathophysiological significance in the parotid of ferret, tissue obtained post-mortem from mature animals of either sex was examined by light microscopical histochemistry for calcium, protein, amino acids, mucosubstances and hydrolases, and by neurohistology. Calcium was localised in acinar cells replete with granules containing protein, disulphides and usually carboxylated mucosubstances. Acid phosphatase activity was basally concentrated in the acinar cells. The granular luminal region of striated ductal cells showed protein, tryptophan, disulphides, neutral mucosubstances, and E600-sensitive esterase and Naphthol AS-D chloroacetate esterase activities, whereas their basal region showed acid phosphatase activity. Strong periluminal activity of acid phosphatase and E600-resistant esterase characterised the collecting ducts. Cholinesterase activity was associated with an extensive network of nerve fibres embracing parenchyma. Catecholamine fluorescence was not seen. beta-glucuronidase reactive macrophages abounded in the interstices. The results suggest that while the acini in the parotid of ferret secrete polyionic glycoproteins, shielded by calcium, the striated ducts secrete tryptophan-rich products comprising neutral glycoproteins and showing proteolytic activity. Innervation is of the cholinergic type and parenchymal lysosomal activity, possibly related to autophagy of stored secretory products and heterophagy of luminal material, is brisk. Macrophages contribute to maintaining the glandular microenvironment, wherein secretory activity appears to be lethargic.

**Descriptors:** ferrets, metabolism, phosphatase analysis, calcium analysis, disulfides analysis, anatomy, histology, hydrolases metabolism, nerve fibers, parotid gland cytology, innervation.

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### Anesthesia / Analgesia

Dunayer, E. (2004). **Ibuprofen toxicosis in dogs, cats, and ferrets.** *Exotic DVM* 99(7): 580-582, 584, 586. ISSN: 8750-7943.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, dogs, cats, ibuprofen, toxicosis.

Fournier Chambrillon, C., J.P. Chusseau, J. Dupuch, C. Maizeret, and P. Fournier (2003). **Immobilization of free-ranging European mink (*Mustela lutreola*) and polecat (*Mustela putorius*) with medetomidine-ketamine and reversal by atipamezole.** *Journal of Wildlife Diseases* 39(2): 393-399. ISSN: 0090-3558.

**NAL Call Number:** 41.9 W648

**Abstract:** From March 1996 to August 1999, 24 free-ranging European mink (*Mustela lutreola*) and 25 free-ranging polecats (*Mustela putorius*) were immobilized for clinical procedures and to place radio transmitters. Data were recorded during 14 and 12 trials, respectively. Animals received intramuscularly 10 mg/kg ketamine (KET) combined with 0.20 mg/kg medetomidine (MED), antagonized by 1.00 mg/kg atipamezole (ATI). Anesthesia times were similar between species. Induction was smooth and rapid (0.7-3.9 min); the degree of anesthesia and muscle relaxation was satisfactory in most animals. Two individuals showed signs of spontaneous recovery before injection of ATI. In other individuals, ATI was injected 28.1-54.0 min after the MED-KET injection and rapidly reversed the effects of the MED. Rectal temperature and heart and respiratory rates decreased significantly 5-25 min post MED-KET injection in both species. Rectal temperature successfully remained stable by placing animals on a warmed plastic table (37 C) during anesthesia. According to these results, this anesthetic protocol produces a safe and rapid immobilization in free-ranging European mink and polecats and is recommended for surgical procedures such as radio transmitter implantation. However caution is required as hypothermia can be severe. Body temperature must be monitored and means provided to maintain stability.

**Descriptors:** ferrets, immobilization, mink, adrenergic alpha agonists, anesthesia recovery period, anesthetics, dissociative antagonists, inhibitors, wild animals, body temperature, heart rate, imidazoles, ketamine, medetomidine, respiration.

Harms, C.A., K.K. Sladky, W.A. Horne, and M.K. Stoskopf (2002). **Epidural analgesia in ferrets.** *Exotic DVM* 4(3): 40-42. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, anesthesia, epidural, analgesia, morphine, pharmacodynamics.

**Notes:** 4th Annual international conference on exotics (ICE2002), Key West, Florida, USA, 2002.

Johnston, M.S. (2005). **Clinical approaches to analgesia in ferrets and rabbits.** *Seminars in Avian and Exotic Pet Medicine* 14(4): 229-235. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, rabbits, analgesia, behavior, ketamine, local anesthetics, non steroidal anti-inflammatory agents, opioids, pain management.

Lawson, A.K., M. Lichtenberger, T. Day, J. Ko, and R. Kirby (2006). **Comparison of sevoflurane and isoflurane in domestic ferrets (*Mustela putorius furo*)**. *Veterinary Therapeutics Research in Applied Veterinary Medicine* 7(3): 207-212. ISSN: 1528-3593.

**Abstract:** Isoflurane anesthesia is commonly used in ferrets for routine examinations and diagnostics.

Sevoflurane is now being used as well, but there have been no studies to date directly comparing these agents in domestic ferrets. A prospective study was designed to evaluate the quality and speed of anesthetic induction and recovery using isoflurane and sevoflurane in ferrets. In addition effects on heart rate, blood pressure and packed cell volume were also recorded. No significant differences were noted between anesthetic agents.

**Descriptors:** domestic ferrets, sevoflurane, isoflurane, comparison, examinations, induction, recovery, heart rate, blood pressure.

Lichtenberger, M. (2005). **Shock, fluid therapy, anesthesia and analgesia in the ferret**. *Exotic DVM* 7(2): 24-30. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, anesthesia, analgesia, hypovolemic shock, corrective fluid therapy, circulatory diseases.

**Notes:** International Conference on Exotics, Ft. Lauderdale, Florida, USA. May 26-28, 2005.

MacPhail, C.M., E. Monnet, J.S. Gaynor, and A. Perini (2004). **Effect of sevoflurane on hemodynamic and cardiac energetic parameters in ferrets**. *American Journal of Veterinary Research* 65(5): 653-658. ISSN: 0002-9645.

**NAL Call Number:** 41.8 Am3A

**Abstract:** **OBJECTIVE:** To determine the effect of sevoflurane on cardiac energetic and hemodynamic parameters in ferrets. **ANIMALS:** 7 healthy domesticated ferrets. **PROCEDURE:** Sevoflurane was used as the sole anesthetic agent for general anesthesia in ferrets. Standard midline laparotomy and median sternotomy were performed to permit instrumentation. Myocardial blood flow was determined by use of colored microsphere technology. Measurements and blood samples were obtained at 1.25%, 2.5%, and 3.75% expired concentration of sevoflurane. **RESULTS:** A dose-dependent decrease in arterial blood pressure, left ventricular pressure, systemic vascular resistance, aortic flow, and dp/dt (an index of contractility) was detected as expired concentration of sevoflurane increased. Heart rate, central venous pressure, coronary vascular resistance, myocardial oxygen extraction ratio, and tau (the time constant of relaxation) were unchanged. Cardiac external work decreased, as did myocardial oxygen consumption, causing increased cardiac efficiency at higher concentrations of sevoflurane. **CONCLUSIONS AND CLINICAL RELEVANCE:** Sevoflurane caused minimal and predictable cardiovascular effects in ferrets without increasing myocardial metabolic demands. Data obtained from this study have not been previously reported for a species that is being commonly used in cardiovascular research. These findings also support use of sevoflurane as a safe inhalant anesthetic in ferrets for clinical and research settings.

**Descriptors:** ferrets, heart, heart rate, methyl ethers, blood flow velocity, blood pressure, dose response relationship, drug, microspheres, oxygen blood, sevoflurane.

Mio, Y., N. Fukuda, Y. Kusakari, Y. Amaki, Y. Tanifuji, and S. Kurihara (2004). **Comparative effects of bupivacaine and ropivacaine on intracellular calcium transients and tension in ferret ventricular muscle**. *Anesthesiology* 101(4): 888-894. ISSN: 0003-3022.

**Abstract:** **BACKGROUND:** Recent evidence suggests that ropivacaine exerts markedly less cardiotoxicity compared with bupivacaine; however, the mechanisms are not fully understood at the molecular level.

**METHODS:** Isolated ferret ventricular papillary muscles were microinjected with the Ca-binding photoprotein aequorin, and intracellular Ca transients and tension were simultaneously measured during twitch in the absence and presence of bupivacaine or ropivacaine. **RESULTS:** Bupivacaine and ropivacaine (10, 30, and 100 microm) reduced peak systolic [Ca]<sub>i</sub> and tension in a concentration-dependent manner. The effects were significantly greater for bupivacaine, particularly on tension (approximately twofold). The percentage reduction of tension was linearly correlated with that of [Ca]<sub>i</sub> for both anesthetics, with the slope of the relationship being approximately equal to 1.0 for ropivacaine and approximately equal to 1.3 for bupivacaine (slope difference,  $P < 0.05$ ), suggesting that the cardiodepressant effect of ropivacaine results predominantly from inhibition of Ca transients, whereas bupivacaine suppresses Ca transients and the reaction beyond Ca transients, i.e., myofibrillar activation, as well. BAY K 8644, a Ca channel opener, abolished the inhibitory effects of ropivacaine on Ca

transients and tension, whereas BAY K 8644 only partially inhibited the effects of bupivacaine, particularly the effects on tension. **CONCLUSION:** The cardiodepressant effect of bupivacaine is approximately twofold greater than that of ropivacaine. Bupivacaine suppresses Ca transients more markedly than does ropivacaine and reduces myofibrillar activation, which may at least in part underlie the greater inhibitory effect of bupivacaine on cardiac contractions. These results suggest that ropivacaine has a more favorable profile as a local anesthetic in the clinical settings.

**Descriptors:** ferrets, anesthetics, pharmacology, bupivacaine, ropivacaine, pharmacology, calcium metabolism, myocardial contraction, tension, comparative effects, heart ventricles.

Rausser, P., J. Zatloukal, A. Necas, J. Lorenzova, and L. Lexmaulova (2002). **Combined medetomidine and ketamine for short-term anaesthesia in ferrets - a clinical study.** *Acta Veterinaria* 71(2): 243-248. ISSN: 0001-7213.

**NAL Call Number:** SF604.87

**Abstract:** We evaluated the quality of anaesthesia by a combination of medetomidine (60 microg/kg intramuscularly) and ketamine given at two different doses (5 mg/kg or 8 mg/kg intramuscularly). Lower ketamine dose resulted in later loss of lateral recumbency, palpebral reflex and deep sensation. It also reduced the time of their recovery. The loss of deep sensation after the high ketamine dose was nearly twice as long as after the low dose. Heart rate values were comparable in both groups and showed a decreasing tendency as well as the respiratory rate which, however, differed in both groups from the 30th min of anaesthesia. The combination of medetomidine and ketamine is very effective for the anaesthesia in ferrets regarding the duration, myorelaxation and analgesia. Prolongation of this anaesthesia is possible with half ketamine doses.

**Descriptors:** ferrets, anesthesia, analgesics, ketamine, duration, behavior, respiration rate, heart rate, clinical trials, blood circulation, time.

Schoemaker, N.J., J.A. Mol, J.T. Lumeij, J.H. Thijssen, and A. Rijnberk (2003). **Effects of anaesthesia and manual restraint on the plasma concentrations of pituitary and adrenocortical hormones in ferrets.** *Veterinary Record* 152(19): 591-595. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Abstract:** Two experiments were carried out to investigate the effect of sampling techniques on the plasma concentrations of pituitary and adrenocortical hormones in ferrets (*Mustela putorius furo*). In the first experiment blood was collected on two occasions from 29 ferrets which were either manually restrained or anaesthetised with isoflurane. In the second experiment eight intact ferrets were fitted with jugular catheters and blood was collected on four occasions, just before and as soon as possible after they had been manually restrained or anaesthetised with medetomidine or isoflurane; blood was also collected 10 and 30 minutes after the induction of anaesthesia. Medetomidine anaesthesia had no effect on the plasma concentrations of pituitary and adrenocortical hormones. Isoflurane anaesthesia resulted in a significant increase in the plasma concentration of alpha-melanocyte-stimulating hormone (alpha-MSH) directly after the induction of anaesthesia. Manual restraint resulted in a significant increase in the plasma concentrations of cortisol and adrenocorticotrophic hormone (ACTH) and a decrease in the plasma concentration of alpha-MSH.

**Descriptors:** anesthesia, ferrets, restraint, specimen handling, blood chemical analysis, corticotropin, blood hydrocortisone, hyperaldosteronism, isoflurane, medetomidine, pituitary adrenal function tests.

Vastenburger, M.H., S.A. Boroffka, and N.J. Schoemaker (2004). **Echocardiographic measurements in clinically healthy ferrets anesthetized with isoflurane.** *Veterinary Radiology & Ultrasound* 45(3): 228-232. ISSN: 1058-8183.

**NAL Call Number:** SF757.8.A4

**Abstract:** Two-dimensional, M4-mode, and color flow Doppler echocardiography was performed in 29 (18 females, 11 males) clinically healthy ferrets anesthetized with isoflurane. M-mode measurements of the left ventricle, left atrial appendage diameter (LAAD), and aorta (Ao) were obtained. The fractional shortening and LAAD/Ao ratio were calculated. The values of the M-mode measurements were compared between the male and female ferrets using a Student's t-test. No significant differences were found. The difference in body weight between the male and female ferrets was highly significant ( $P < 0.001$ ), but no significant correlation was found between body weight and M-mode measurements. Color flow Doppler examinations of the mitral, tricuspid, aortic, and pulmonary valves were recorded and there was minor valvular regurgitation in five ferrets, which was considered nonsignificant.

**Descriptors:** anesthesia, anesthetics, inhalation pharmacology, ferrets, heart ventricles, isoflurane, ultrasonography, reference values, doppler ultrasonography, echocardiography.

Wilkens, E.P. and B.J. Yates (2005). **Pretreatment with ondansetron blunts plasma vasopressin increases associated with morphine administration in ferrets.** *Anesthesia and Analgesia* 101(4): 1029-1033. ISSN: 0003-2999.

**Abstract:** Postoperative nausea and vomiting are significant problems. A method for measuring vomiting thresholds for anesthetics using plasma markers, such as arginine vasopressin (AVP), would be useful. We measured the change in AVP concentrations associated with morphine alone or in combination with ondansetron pretreatment. Data were collected from ferrets implanted with IV catheters. After recovery, the ferrets were administered IV morphine alone or with ondansetron pretreatment. Baseline blood samples were taken before morphine injection, and at 5, 10, 15, 30, 45, 60, and 90 min after morphine injection. Plasma AVP levels were measured using radioimmunoassay. Morphine alone was associated with a significant increase in plasma AVP concentrations from baseline at 45, 60, and 90 min ( $P < 0.05$ ). Ondansetron alone did not change the plasma AVP concentration after 20 min ( $P > 0.46$ ). There was no significant increase ( $P > 0.46$ ) in AVP concentration in animals that were pretreated with ondansetron before administration of morphine. Two-way analysis of variance confirmed that ondansetron significantly decreased the increase in AVP by morphine at 60 and 90 min ( $P < 0.05$ ). These data suggest that plasma AVP concentration may be an accurate marker for nausea, and may be useful to guide treatment for this condition. **IMPLICATIONS:** The antiemetic, ondansetron, has an effect not only on clinically perceived vomiting, but also on plasma vasopressin level.

**Descriptors:** ferrets, antiemetics, morphine, ondansetron, nausea, postoperative nausea, prevention and control of vomiting.

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### Animal Models

Brown, C. (2006). **Blood collection from the cranial vena cava of the ferret.** *Lab Animal* 35(9): 23-24. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Abstract:** The domestic ferret, though not as common a laboratory animal as the rat or mouse, serves as a model in critical research areas, including influenza biology and vaccine development. Studies involving ferrets necessitate knowledge of proper blood collection methods, such as cranial vena cava puncture.

**Descriptors:** ferret, blood collection, cranial vena cava, animal model, research.

Endo, T., M. Minami, M. Hirafuji, N. Hamaue, and S.H. Parvez (2004). **The ferret: A cytotoxic drug-induced emesis model.** *Biogenic Amines* 18(3-6): 419-434. ISSN: 0168-8561.

**Descriptors:** ferret, animal model, emesis, Mustela, cytotoxic drugs, vagus nerve, emetic stimuli, Cisplatin induced, vagotomy.

Gierdalski, M., S.P. Sardi, G. Corfas, and S.L. Juliano (2005). **Endogenous neuregulin restores radial glia in a (ferret) model of cortical dysplasia.** *Journal of Neuroscience* 25(37): 8498-8504. ISSN: 1529-2401.

**Abstract:** Radial glia are integral components of the developing neocortex. During corticogenesis, they form an important scaffold for neurons migrating into the cortical plate. Recent attention has focused on neuregulin (NRG1), acting through erbB receptors, in maintaining their morphology. We developed a model of developmental radial glial disruption by delivering an antimetabolic [methylazoxymethanol (MAM)] to pregnant ferrets on embryonic day 24 (E24). We previously found that normal ferret cortex contains a soluble factor capable of realigning the disorganized radial glia back toward their normal morphology. Characterization of the reorganizing activity in normal cortex demonstrated that the probable factor mediating these responses was a 30-50 kDa protein. To test whether this endogenous soluble factor was NRG1, we used organotypic cultures of E24 MAM-treated ferret neocortex supplemented with the endogenous factor obtained from normal cortical implants, exogenous NRG1beta, antibodies that either blocked or stimulated erbB receptors, or a soluble erbB subtype that binds to available NRG1. We report that exogenous NRG1 or antibodies that stimulate erbB receptors dramatically improve the morphology of disrupted radial glia, whereas blockade of NRG1-erbB signaling prevents the radial glial repair. Our results suggest that NRG1 is an endogenous factor in ferret neocortex capable of repairing damaged radial glia and that it acts via one or more erbB receptors.

**Descriptors:** ferrets, cerebral cortex, neuregulins, neuroglia, animal models, newborn disease models, methylazoxymethanol acetate, prenatal exposure, corticogenesis.

He, T., H. Friede, and S. Kiliaridis (2002). **Dental eruption and exfoliation chronology in the ferret (*Mustela putorius furo*).** *Archives of Oral Biology* 47(8): 619-623. ISSN: 0003-9969.

**NAL Call Number:** RK1.A6989

**Abstract:** Substituting ferrets for rats and dogs as animal models for craniofacial research is favourable because of the similarity of many of the ferret's anatomical, metabolic and physiological features to those of man. Other advantages are cost-effectiveness and possibly less ethical controversy. However, information on the dental

chronology of ferrets needs to be supplemented if this animal is to be promoted as an alternative model. Dental development was here examined in 16 ferrets (eight males, eight females) from three litters at between 12 and 90 days of age. Dental eruption and exfoliation were assessed and recorded every second day. The sequence of eruption of deciduous and permanent teeth was determined and data were analysed statistically. Also, any sex-related differences in eruption and exfoliation ages were defined. No deciduous incisors were observed to erupt in this group of animals. Other deciduous teeth erupted between the 19th and 31st postnatal days, and exfoliated between days 51 and 76. The time of eruption of the permanent teeth ranged from 42 to 77 days, in accordance with the stage of the mixed dentition. The female ferrets were generally ahead of the males in the exfoliation age of their deciduous teeth and the eruption age of their permanent teeth, but this, a sex difference did not apply to the eruption age of the deciduous teeth. These extended basic data might facilitate the introduction of this alternative experimental animal into craniofacial research.

**Descriptors:** ferrets physiology, animal models, tooth eruption physiology, tooth exfoliation, deciduous teeth, aging physiology, sex factors.

He, T. and S. Kiliaridis (2003). **Effects of masticatory muscle function on craniofacial morphology in growing ferrets (*Mustela putorius furo*)**. *European Journal of Oral Sciences* 111(6): 510-517. ISSN: 0909-8836.

**Abstract:** Studying the effects of masticatory muscle function on craniofacial morphology in animal models with different masticatory systems is important for further understanding of related issues in humans. Forty 5-wk-old male ferrets were equally divided into two groups. One group was fed a diet of hard pellets (HDG) and the other group was fed the same diet but softened with water (SDG). Lateral and dorsoventral cephalograms were taken on each group after 6 months. Cephalometric measurements were performed by digital procedures. For SDG ferrets, the hard palate plane was more distant from the cranial base plane, and canines were more proclined compared with HDG ferrets. The SDG ferrets were also found to have smaller interfrontal and interparietal widths, and a slenderer zygomatic arch than the HDG ferrets. In the mandible, the coronoid process was generally shorter and narrower for the SDG ferrets. The effects of the altered masticatory muscle function on craniofacial morphology in growing ferrets seemed to differ from those previously reported in other animal models studied under similar experimental conditions. Such differences in the effects are presumably related to the differences in the mode of mastication, craniofacial anatomy and growth pattern in different animal models.

**Descriptors:** ferret growth and development, mastication, masticatory muscles, maxillofacial development, skull growth and development, feed, nutrition, facial bones, mandible.

Herlocher, M.L., R. Truscon, R. Fenton, A. Klimov, S. Elias, S.E. Ohmit, and A.S. Monto (2003). **Assessment of development of resistance to antivirals in the ferret model of influenza virus infection**. *Journal of Infectious Diseases* 188(9): 1355-1361. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** We attempted to develop in vivo resistance of influenza virus to amantadine and to zanamivir, by use of the ferret model of influenza virus infection. Resistance of influenza virus A/LosAngeles/1/87 (H3N2) to amantadine was generated within 6 days, during a single course of treatment, and mutations in the M2 gene that are characteristic of human infections were observed. In contrast, during an identical single course of treatment with zanamivir, no evidence of reduced susceptibility was demonstrated. Pooled virus shed by zanamivir-treated ferrets was used to infect another group of ferrets. Twenty virus clones grew in plaque assays containing zanamivir, indicating possible reduced susceptibility; however, none exhibited reduced susceptibility to zanamivir in neuraminidase (NA) inhibition assays. Sequencing of the NA gene of these clones revealed only a noncoding nucleotide mutation at position 685. Sequencing of the hemagglutinin gene revealed mutations at positions 53, 106, 138, 145, 166, and 186. Similar to the situation in humans, amantadine use in ferrets rapidly produces antiviral resistance, but zanamivir use does not, although nucleotide changes were observed.

**Descriptors:** ferrets, amantadine, antiviral agents, influenza A virus, orthomyxoviridae infections, sialic acids, animal disease models, drug resistance, viral genetics, guanidines, hemagglutination inhibition tests, viral chemistry, RNA, reverse transcriptase polymerase chain reaction, DNA sequence analysis.

Howard, J., P.E. Marinari, and D.E. Wildt (2003). **Black-footed ferret: Model for assisted reproductive technologies contributing to in situ conservation**. *Conservation Biology Series* 8: 249-266.

**Descriptors:** *Mustela nigripes*, black footed ferrets, breeding and reintroduction program, USA, reproductive technology, in situ conservation.

Jacobs, K.M. (2004). **A ferret model of microgyria: The effect of varying lesion days.** *Epilepsia* 45(Suppl. 7): 44. ISSN: 0013-9580.

**Descriptors:** ferrets as animal models, microgyria, varying lesions, nervous system diseases, epilepsy.

**Notes:** 58th Annual Meeting of the American-Epilepsy-Society, New Orleans, LA, USA; December 03 -07, 2004.

Johnson Delaney, C.A. (2005). **The ferret gastrointestinal tract and *Helicobacter mustelae* infection.** *Veterinary Clinics of North America. Exotic Animal Practice* 8(2): 197-212. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Descriptors:** ferrets, microbiology, gastrointestinal tract, helicobacter infections, *Helicobacter mustelae* pathogenicity, biliary tract, disease models, pancreas, exocrine physiology.

Kim, Y., N. Chongviriyaphan, C. Liu, R.M. Russell, and X.D. Wang (2006). **Combined antioxidant (beta-carotene, alpha-tocopherol and ascorbic acid) supplementation increases the levels of lung retinoic acid and inhibits the activation of mitogen-activated protein kinase in the ferret lung cancer model.** *Carcinogenesis* 27(7): 1410-1419. ISSN: 0143-3334.

**Abstract:** Interactions among beta-carotene (BC), alpha-tocopherol (AT) and ascorbic acid (AA) led to the hypothesis that using a combination of these antioxidants could be more beneficial than using a single antioxidant alone, particularly against smoke-related lung cancer. In this investigation, we have conducted an animal study to determine whether combined BC, AT and AA supplementation (AOX) protects against 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK)-induced lung carcinogenesis in smoke-exposed (SM) ferrets. Ferrets were treated for 6 months in the following four groups: (i) control, (ii) SM + NNK, (iii) AOX and (iv) SM + NNK + AOX. Results showed that the combined AOX supplementation (i) prevented the SM + NNK-decreased lung concentrations of retinoic acid (RA) and BC; (ii) inhibited the SM + NNK-induced phosphorylation of Jun N-terminal kinase (JNK), extracellular-signal-regulated protein kinase (ERK) and proliferating cellular nuclear antigen proteins in the lungs of ferrets; and (iii) blocked the SM + NNK-induced up-regulation of total p53 and Bax proteins, as well as phosphorylated p53 in the lungs of ferrets. In addition, there were no lesions observed in the lung tissue of ferrets in the control and/or the AOX groups after 6 months of intervention, but combined AOX supplementation resulted in a trend toward lower incidence of both preneoplastic lung lesions and lung tumor formation in SM + NNK + AOX group of ferrets, as compared with the SM + NNK group alone. These data indicate that combined AOX supplementation could be a useful chemopreventive strategy against lung carcinogenesis through maintaining normal tissue levels of RA and inhibiting the activation of mitogen-activated protein kinase pathways, cell proliferation and phosphorylation of p53.

**Descriptors:** ferrets, animal model, lung neoplasms, ascorbic acid, carcinogens, immunohistochemistry, lung metabolism, nitrosamines, tobacco smoke pollution, tumor suppressor, protein metabolism, beta carotene.

Kim, Y., X. Liu S, C. Liu, D. Smith E, R. Russell M, and X. Wang D (2006). **Induction of pulmonary neoplasia in the smoke-exposed ferret by 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK): A model for human lung cancer.** *Cancer Letters* 234(2): 209-219. ISSN: 0304-3835.

**Abstract:** Research into dietary chemoprevention against lung carcinogenesis has been limited by the lack of appropriate animal models that closely mimic smoking-related human lung cancer. Ferrets (*Mustela putorius furo*) have been used to study the biologic activities of carotenoids against smoke-induced lung lesions, but this model has yet to be thoroughly established and validated. To determine the appropriateness of the ferret as a model for human lung cancer, we have performed a 6-month in vivo study in ferrets exposed to both tobacco smoke and a carcinogen (4-(N-methyl-N-nitrosamino)-1-(3-pyridyl)-1-butanone, NNK) found in cigarette smoke. Results showed that six out of 12 ferrets exposed to both NNK injection and cigarette smoke developed grossly identifiable lung tumors whereas none of nine ferrets from the sham treatment group developed any lung lesions. The histopathological types of these tumors (squamous cell carcinoma, adenosquamous carcinoma and adenocarcinoma) in ferret lungs are very similar to those in humans. In addition, 10 out of 12 ferrets exposed to both NNK and cigarette smoke developed preneoplastic lesions (squamous metaplasia, dysplasia, and atypical adenomatous hyperplasia) with complex growth patterns whereas the sham group did not show any of these lesions. Furthermore, the expression of proliferating cellular nuclear antigen increased markedly in both gross

tumors and preneoplastic lesions in the lungs. In summary, the development of both preneoplastic lesions and gross lung tumors in ferrets provides an excellent and unique model for studying lung cancer chemoprevention with agents such as carotenoids, and for studying the molecular mechanism of carcinogenesis in the earlier stages of smoke-related lung cancer.

**Descriptors:** ferret, animal model, lung carcinogenesis, lung cancer, pulmonary neoplasia, carotenoids, cigarette smoke.

Lambkin, R., J.S. Oxford, S. Bossuyt, A. Mann, I.C. Metcalfe, C. Herzog, J.F. Viret, and R. Gluck (2004). **Strong local and systemic protective immunity induced in the ferret model by an intranasal virosome-formulated influenza subunit vaccine.** *Vaccine* 22(31-32): 4390-4396. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** The proliferation of influenza viruses causes costly, recurrent, annual epidemics. Current vaccines, mainly administered parenterally, have been shown to be suboptimal in terms of efficacy, particularly where local IgA responses are concerned. Recent investigations of virosomes as delivery systems for viral HA and NA antigens have demonstrated an improved immune response. This paper investigates the efficacy of a novel virosome-based intranasal influenza vaccine by its ability to reduce disease symptoms and its effect on viral shedding in nasal secretions of immunised ferrets. The use of ferrets in the study of influenza vaccines is based on the good comparability between ferret and human response to the disease. Intranasal, as opposed to parenteral, administration of a trivalent virosome-based subunit vaccine adjuvanted with HLT provides an almost total prevention of virus shedding combined with a high level of immunological protection against homologous virus challenge. The ease of application of an intranasal vaccine may have positive repercussions in the adoption of influenza vaccinations, particularly in 'at-risk' groups.

**Descriptors:** ferrets, orthomyxoviridae infections, intranasal administration, influenza A virus, influenza B virus, influenza vaccines, orthomyxoviridae infections, virus shedding.

Lau, A.H.Y., K.K.W. Kan, H.W. Lai, M.P. Ngan, J.A. Rudd, and D.T.W. Yew (2003). **Action of emetic drugs in the ferret and *Suncus murinus* (house musk shrew): New models of nausea?** *Journal of Veterinary Pharmacology and Therapeutics* 26(Supplement 1): 157. ISSN: 0140-7783.

**NAL Call Number:** SF915.J63

**Descriptors:** emesis, ferret, musk shrew, animal models, emetic drugs, action, nausea, meeting abstract.

**Notes:** Proceedings of the 9th International Congress of the European Association for Veterinary Pharmacology and Toxicology, Lisbon, Portugal; July 13-18, 2003.

Li, Z. and J.F. Engelhardt (2003). **Progress toward generating a ferret model of cystic fibrosis by somatic cell nuclear transfer.** *Reproductive Biology and Endocrinology* 1: 83. ISSN: 1477-7827.

**Abstract:** Mammalian cloning by nuclear transfer from somatic cells has created new opportunities to generate animal models of genetic diseases in species other than mice. Although genetic mouse models play a critical role in basic and applied research for numerous diseases, often mouse models do not adequately reproduce the human disease phenotype. Cystic fibrosis (CF) is one such disease. Targeted ablation of the cystic fibrosis transmembrane conductance regulator (CFTR) gene in mice does not adequately replicate spontaneous bacterial infections observed in the human CF lung. Hence, several laboratories are pursuing alternative animal models of CF in larger species such as the pig, sheep, rabbits, and ferrets. Our laboratory has focused on developing the ferret as a CF animal model. Over the past few years, we have investigated several experimental parameters required for gene targeting and nuclear transfer (NT) cloning in the ferret using somatic cells. In this review, we will discuss our progress and the hurdles to NT cloning and gene-targeting that accompany efforts to generate animal models of genetic diseases in species such as the ferret.

**Descriptors:** ferrets, cell nucleus transplantation, cystic fibrosis, animal disease models, cell nucleus, cloning, fibroblasts.

Li, Z., Q. Jiang, M. Rezaei Sabet, Y. Zhang, T.C. Ritchie, and J.F. Engelhardt (2002). **Conditions for in vitro maturation and artificial activation of ferret oocytes.** *Biology of Reproduction* 66(5): 1380-1386. ISSN: 0006-3363.

**Abstract:** The ferret represents an attractive species for animal modeling of lung diseases because of the similarity between ferret and human lung biology and its relatively small size and short gestation time. In an

effort to establish experimental protocols necessary for cloning ferrets, optimized conditions for in vitro maturation and artificial activation of ferret oocytes were examined. Cumulus-oocyte complexes were harvested from ovaries of superovulated ferrets, and in vitro maturation was evaluated in three different culture media: medium 1 (TCM-199 + 10% FBS), medium 2 (TCM-199 + 10% FBS with eCG [10 IU/ml] and hCG [5 IU/ml]), or medium 3 (TCM-199 + 10% FBS with eCG, hCG, and 17beta-estradiol [2 microg/ml]). After 24 h of maturation in vitro, the maturation rate of oocytes cultured in medium 2 (70%, n = 79) was significantly greater ( $P < 0.01$ ) than those of oocytes cultured in the other two media (27%-36%, n = 67-73). At 48 h, similar maturation rates (56%-69%, n = 76-87) were observed for all three types of media. For activation experiments, oocytes cultured in medium 2 were stimulated with electrical and chemical stimuli either individually or in combination. Treatment with cycloheximide and 6-dimethylaminopurine (6-DMAP) following electrical stimulation resulted in 43% (n = 58) of the oocytes developing to the blastocyst stage. Such an activation rate represented a significant improvement over those obtainable under other tested conditions, including individual treatment with electrical pulses (10%, n = 41), cycloheximide (3%, n = 58), or 6-DMAP (5%, n = 59). Blastocysts derived from in vitro activation appeared to be normal morphologically and were composed of an appropriate number of both inner cell mass (mean +/- SEM, 10.3 +/- 1.1; n = 11) and trophectoderm (60.8 +/- 2.9, n = 11) cells. These results have begun to elucidate parameters important for animal modeling and cloning with ferrets.

**Descriptors:** ferrets, oocytes, animal model, lung diseases, cycloheximide, electric stimulation, embryonic and fetal development, fertilization in vitro, parthenogenesis, protein synthesis inhibitors, superovulation, ferret lung, human lung, cloning.

Li, Z., X. Sun, J. Chen, G.H. Leno, and J.F. Engelhardt (2006). **Factors affecting the efficiency of embryo transfer in the domestic ferret (*Mustela putorius furo*)**. *Theriogenology* 66(2): 183-190. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Abstract:** Embryo transfer (ET) to recipient females is a foundational strategy for a number of assisted reproductive technologies, including cloning by somatic cell nuclear transfer. In an attempt to develop efficient ET in domestic ferrets, factors affecting development of transferred embryo were investigated. Unilateral and bilateral transfer of zygotes or blastocysts in the oviduct or uterus was evaluated in recipient nulliparous or primiparous females. Developing fetuses were collected from recipient animals 21 days post-copulation and examined. The percentage of fetal formation was different ( $P < 0.05$ ) for unilateral and bilateral transfer of zygotes (71%) in nulliparous females with bilateral transfer (56%) in primiparous recipients. The percentage (90%) of fetal formation in nulliparous recipients following unilateral transfer of blastocysts was higher ( $P < 0.05$ ) than that observed in primiparous recipients with bilateral ET (73%). Notably, the percentage of fetal formation was higher ( $P < 0.05$ ) when blastocysts were transferred as compared to zygotes (90% versus 71%). Transuterine migration of embryos occurred following all unilateral transfers and also in approximately 50% of bilateral transfers with different number of embryos in each uterine horn. These data will help to facilitate the development of assisted reproductive strategies in the ferret and could lead to the use of this species for modeling human disease and for conservation of the endangered Mustelidae species such as black-footed ferret and European mink.

**Descriptors:** ferret, embryo transfer, factors, efficiency, reproductive technologies, animal model.

Li, Z., X. Sun, J. Chen, X. Liu, S.M. Wisely, Q. Zhou, J.P. Renard, G.H. Leno, and J.F. Engelhardt (2006). **Cloned ferrets produced by somatic cell nuclear transfer**. *Developmental Biology* 293(2): 439-448. ISSN: 0012-1606.

**NAL Call Number:** 442.8 D49

**Abstract:** Somatic cell nuclear transfer (SCNT) offers great potential for developing better animal models of human disease. The domestic ferret (*Mustela putorius furo*) is an ideal animal model for influenza infections and potentially other human respiratory diseases such as cystic fibrosis, where mouse models have failed to reproduce the human disease phenotype. Here, we report the successful production of live cloned, reproductively competent, ferrets using species-specific SCNT methodologies. Critical to developing a successful SCNT protocol for the ferret was the finding that hormonal treatment, normally used for superovulation, adversely affected the developmental potential of recipient oocytes. The onset of Oct4 expression was delayed and incomplete in parthenogenetically activated oocytes collected from hormone-treated females relative to oocytes collected from females naturally mated with vasectomized males. Stimulation

induced by mating and in vitro oocyte maturation produced the optimal oocyte recipient for SCNT. Although nuclear injection and cell fusion produced mid-term fetuses at equivalent rates (approximately 3-4%), only cell fusion gave rise to healthy surviving clones. Single cell fusion rates and the efficiency of SCNT were also enhanced by placing two somatic cells into the perivitelline space. These species-specific modifications facilitated the birth of live, healthy, and fertile cloned ferrets. The development of microsatellite genotyping for domestic ferrets confirmed that ferret clones were genetically derived from their respective somatic cells and unrelated to their surrogate mother. With this technology, it is now feasible to begin generating genetically defined ferrets for studying transmissible and inherited human lung diseases. Cloning of the domestic ferret may also aid in recovery and conservation of the endangered black-footed ferret and European mink.

**Descriptors:** ferrets, cell nucleus transplantation, cloning, genetics, cell fusion, embryo transfer, fetal development, microinjections, oocytes.

Liu, C., F. Lian, D.E. Smith, R.M. Russell, and X.D. Wang (2003). **Lycopene supplementation inhibits lung squamous metaplasia and induces apoptosis via up-regulating insulin-like growth factor-binding protein 3 in cigarette smoke-exposed ferrets.** *Cancer Research* 63(12): 3138-3144. ISSN: 0008-5472.

**Abstract:** Higher intake of lycopene is related to a lower risk of lung cancer in human studies. Lung cancer risk is associated with higher plasma levels of insulin-like growth factor I (IGF-I) and/or lower levels of IGF-binding protein 3 (IGFBP-3). However, little is known regarding whether lycopene can inhibit cigarette smoke-induced lung carcinogenesis through modulation of IGF-I/IGFBP-3, cell proliferation, and apoptosis. We investigated the effects of lycopene supplementation at a low dose (1.1 mg/kg/day, which is equivalent to an intake of 15 mg/day in humans) and a high dose (4.3 mg/kg/day, which is equivalent to 60 mg/day in humans) on plasma IGF-I/IGFBP-3 levels, histopathological changes, proliferating cellular nuclear antigen (PCNA) expression, BAD phosphorylation, and apoptosis (caspase 3 assay) in lungs of ferrets with or without cigarette smoke exposure for 9 weeks. We found that ferrets supplemented with lycopene and exposed to smoke had significantly higher plasma IGFBP-3 levels ( $P < 0.01$ ) and a lower IGF-I/IGFBP-3 ratio ( $P < 0.01$ ) than ferrets exposed to smoke alone. Both low- and high-dose lycopene supplementations substantially inhibited smoke-induced squamous metaplasia and PCNA expression in the lungs of ferrets. No squamous metaplasia or PCNA overexpression were found in the lungs of control ferrets or those supplemented with lycopene alone.

Furthermore, cigarette smoke exposure greatly increased BAD phosphorylation at both Ser(136) and Ser(112) and significantly decreased cleaved caspase 3 in the lungs of ferrets, as compared with controls. The elevated phosphorylation of BAD and down-regulated apoptosis induced by cigarette smoke in the lungs of ferrets was prevented by both low- and high-dose lycopene supplementations. Lycopene levels were increased in a dose-dependent manner in both plasma and lungs of ferrets supplemented with lycopene alone. However, lycopene levels were markedly lower in both plasma and lungs of ferrets supplemented with lycopene and exposed to smoke. Furthermore, smoke exposure increased cis isomers (26% for 13-cis and 22% for 9-cis) of lycopene in the lungs of ferrets, compared with that of ferrets supplemented with lycopene alone (20% for 13-cis and 14% for 9-cis). In conclusion, lycopene may mediate its protective effects against smoke-induced lung carcinogenesis in ferrets through up-regulating IGFBP-3 and down-regulating phosphorylation of BAD, which promote apoptosis and inhibit cell proliferation.

**Descriptors:** ferrets, anticarcinogenic agents, apoptosis, carotenoids, adverse effects of smoke, anticarcinogenic agents, carrier proteins, caspases, cell division, dietary supplements, drug evaluation, lung metabolism, metaplasia, animal models, phosphorylation, post translational drug effects.

Liu, C., R.M. Russell, and X.D. Wang (2006). **Lycopene supplementation prevents smoke-induced changes in p53, p53 phosphorylation, cell proliferation, and apoptosis in the gastric mucosa of ferrets.** *Journal of Nutrition* 136(1): 106-111. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Abstract:** Cigarette smoking increases the risk for gastric cancer. Higher intakes or blood levels of lycopene are associated with a decreased risk of gastric cancer. However, the biological mechanisms by which lycopene may protect against gastric carcinogenesis are poorly understood. We evaluated the effects of lycopene supplementation on smoke-induced changes in protein levels of p53, p53 target genes (p21<sup>superscript</sup> Waf1/Cip1] and Bax-1), cell proliferation, and apoptosis in the gastric mucosa of ferrets. Ferrets were assigned to cigarette smoke exposure or to no exposure and to no, low-dose, or high-dose lycopene supplementation (2 x 3 factorial design) for 9 wk. Lycopene concentrations were significantly elevated in a dose-dependent manner in

the gastric mucosa of ferrets supplemented with lycopene alone, but were markedly reduced in ferrets supplemented with lycopene and exposed to smoke. Although ferrets were given lycopene containing 95% all-trans isomers, cis isomers were the predominant forms in the gastric mucosa. Total p53 and phosphorylated p53 levels were greater in ferrets exposed to smoke alone than in all other groups. Levels were [approximately]300 and 500% of the controls, respectively. However, smoke-elevated total p53 and phosphorylated p53 were markedly attenuated by both doses of lycopene. p21<sup>[superscript Waf1/Cip1]</sup>, Bax-1, and cleaved caspase 3 were substantially decreased, whereas cyclin D1 and proliferating cellular nuclear antigen (PCNA) were increased in ferrets exposed to smoke alone. Lycopene prevented smoke-induced changes in p21<sup>[superscript Waf1/Cip1]</sup>, Bax-1, cleaved caspase 3, cyclin D1, and PCNA in a dose-dependent fashion. These data indicate that lycopene may prevent smoke exposure-induced changes in p53, p53 phosphorylation, p53 target genes, cell proliferation, and apoptosis in the gastric mucosa of ferrets.

**Descriptors:** ferrets, animal disease models, smoking habit, lycopene, dietary supplements, protein phosphorylation, cell proliferation, apoptosis, human health, gastric mucosa, cigarettes, gastric cancer, human diseases, chemoprevention, gene expression, proliferating cell nuclear antigen, cyclins, animal proteins.

Maher, J.A. and J. DeStefano (2004). **The ferret: An animal model to study influenza virus.** *Lab Animal* 33(9): 50-53. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Abstract:** There has been much critical influenza research conducted in a little-known laboratory animal--the ferret. The authors review some of these findings, discuss the reasons the ferret often becomes a model for influenza infection, and compare the ferret with other animal models.

**Descriptors:** ferrets, animal models, orthomyxoviridae, influenza, literature review.

Maines, T.R., L.M. Chen, Y. Matsuoka, H. Chen, T. Rowe, J. Ortin, A. Falcon, T.H. Nguyen, I.Q. Mai, E.R. Sedyaningsih, S. Harun, T.M. Tumpey, R.O. Donis, N.J. Cox, K. Subbarao, and J.M. Katz (2006). **Lack of transmission of H5N1 avian-human reassortant influenza viruses in a ferret model.** *Proceedings of the National Academy of Sciences of the United States of America* 103(32): 12121-12126. ISSN: 0027-8424.

**Abstract:** Avian influenza A H5N1 viruses continue to spread globally among birds, resulting in occasional transmission of virus from infected poultry to humans. Probable human-to-human transmission has been documented rarely, but H5N1 viruses have not yet acquired the ability to transmit efficiently among humans, an essential property of a pandemic virus. The pandemics of 1957 and 1968 were caused by avian-human reassortant influenza viruses that had acquired human virus-like receptor binding properties. However, the relative contribution of human internal protein genes or other molecular changes to the efficient transmission of influenza viruses among humans remains poorly understood. Here, we report on a comparative ferret model that parallels the efficient transmission of H3N2 human viruses and the poor transmission of H5N1 avian viruses in humans. In this model, an H3N2 reassortant virus with avian virus internal protein genes exhibited efficient replication but inefficient transmission, whereas H5N1 reassortant viruses with four or six human virus internal protein genes exhibited reduced replication and no transmission. These findings indicate that the human virus H3N2 surface protein genes alone did not confer efficient transmissibility and that acquisition of human virus internal protein genes alone was insufficient for this 1997 H5N1 virus to develop pandemic capabilities, even after serial passages in a mammalian host. These results highlight the complexity of the genetic basis of influenza virus transmissibility and suggest that H5N1 viruses may require further adaptation to acquire this essential pandemic trait.

**Descriptors:** ferrets virology, influenza A virus, H5N1, metabolism, human transmission, human virology, reassortant viruses, metabolism, disease models, virus replication.

Mann, A., A.C. Marriott, S. Balasingam, R. Lambkin, J.S. Oxford, and N.J. Dimmock (2006). **Interfering vaccine (defective interfering influenza A virus) protects ferrets from influenza, and allows them to develop solid immunity to reinfection.** *Vaccine* 24(20): 4290-4296. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Defective interfering (DI) virus RNAs result from major deletions in full-length viral RNAs that occur spontaneously during de novo RNA synthesis. These RNAs are packaged into virions that are by definition non-infectious, and are delivered to cells normally targeted by the virion. DI RNAs can only replicate with the aid of a coinfecting infectious helper virus, but the small size of DI RNA allows more copies of it to be made than of

its full-length counterpart, so the cell produces defective virions in place of infectious progeny. In line with this scenario, the expected lethal disease in an influenza A virus-mouse model is made subclinical by administration of DI virus, but animals develop solid immunity to the infecting virus. Hence DI virus has been called an 'interfering vaccine'. Because interfering vaccine acts intracellularly and at a molecular level, it should be effective against all influenza A viruses regardless of subtype. Here we have used the ferret, widely acknowledged as the best model for human influenza. We show that an interfering vaccine with defective RNAs from an H3N8 virus almost completely abolished clinical disease caused by A/Sydney/5/97 (H3N2), with abrogation of fever and significant reductions in clinical signs of illness. Animals recovered fully and were solidly immune to reinfection, in line with the view that treatment converts the otherwise virulent disease into a subclinical and immunizing infection.

**Descriptors:** influenza vaccines, administration, dosage, influenza virus A immunology, ferrets, mice, orthomyxoviridae infections, immunology.

Mishin, V.P., M.S. Nedyalkova, F.G. Hayden, and L.V. Gubareva (2005). **Protection afforded by intranasal immunization with the neuraminidase-lacking mutant of influenza A virus in a ferret model.** *Vaccine* 23(22): 2922-2927. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Protective efficacy of the intranasal immunization with the neuraminidase (NA)-deficient mutant of the influenza A virus was investigated in ferrets. Despite the highly attenuated replication in vivo, the mutant completely protected the animals against the wild type virus challenge. When challenge was done with antigenic drift variants, significant reductions in the viral titers, inflammatory cell counts, and protein concentrations were observed in the nasal washes of the immunized animals. The genetically engineered NA-deficient mutant also protected animals against the challenge and induced humoral immune response against the foreign protein that replaced the NA. We conclude that the NA as antigen is dispensable in the live attenuated influenza virus vaccine and that the NA-lacking mutant can be used as a virus vector.

**Descriptors:** ferrets, influenza A virus, vaccine administration, neuraminidase genetics, orthomyxoviridae infections, intranasal administration, virus enzymology, genetics, animal models.

Odekunle, A. and T.I. Chinnah (2003). **Brainstem origin of duodenal vagal preganglionic parasympathetic neurons. A WGA-HRP study in the ferret (*Mustela Putorius Furo*), a human model.** *West Indian Medical Journal* 52(4): 267-272. ISSN: 0043-3144.

**Abstract:** The projections of vagal brainstem neurons to the duodenal segment of the gastrointestinal tract were studied in the ferret using the WGA-HRP neurohistochemical technique. Fourteen adult ferrets with weights ranging from 800 gm to 1500 gm were used for the study. The muscular wall of the duodenum of six ferrets was injected with 0.1 ml of 5% WGA-HRP in 0.5 M sodium chloride. The eight remaining ferrets were used as controls. Two of these had injections of 0.1 ml normal saline into the muscular wall of the duodenum. The second set of two ferrets was injected with 0.1 ml of 5% WGA-HRP in buffer after bilateral truncal vagotomy. The third set of two ferrets received intraperitoneal injection of 0.1 ml of 5% WGA-HRP while, in the last set, the tracer was injected into the hepatic portal vein. Following the injections, the ferrets were allowed to survive for 48-72 hours after which each ferret was perfused transcardially first with normal saline followed by a fixative containing 1% paraformaldehyde and 1.25% glutaraldehyde in 0.1 M phosphate buffer, pH 7.4 at room temperature and finally with 10% buffered sucrose at 4 degrees C. Transverse serial frozen sections of the brainstem were then taken and processed for WGA-HRP neurohistochemistry and were analyzed under light and dark-field illuminations. The analyses of the sections taken from the six ferrets injected with WGA-HRP revealed neurons labelled with the tracer in the dorsal motor nucleus of the vagus nerve (DMNV). Sections taken from the control ferrets did not reveal any WGA-HRP labelled neurons in the brainstem.

**Descriptors:** ferrets, preganglionic autonomic fibers, duodenum innervation, molecular probes, parasympathetic nervous system, vagus nerve, animal models, neural pathways.

Olsen, A.K. (2005). **Ilderen som forsogsdyr. [Ferrets as experimental animals].** *Dansk Veterinaertidsskrift* 88(6): 8-9. ISSN: 0106-6854.

**Descriptors:** ferrets, research, brain, disease models, laboratory animals, stomach ulcers, vaccination, viruses.

**Language of Text:** Danish.

Peltola, V.T., K.L. Boyd, J.L. McAuley, J.E. Rehg, and J.A. McCullers (2006). **Bacterial sinusitis and otitis media following influenza virus infection in ferrets.** *Infection and Immunity* 74(5): 2562-2567. ISSN: 1098-5522.  
**NAL Call Number:** QR1.I57

**Abstract:** *Streptococcus pneumoniae* is the leading cause of otitis media, sinusitis, and pneumonia. Many of these infections result from antecedent influenza virus infections. In this study we sought to determine whether the frequency and character of secondary pneumococcal infections differed depending on the strain of influenza virus that preceded bacterial challenge. In young ferrets infected with influenza virus and then challenged with pneumococcus, influenza viruses of any subtype increased bacterial colonization of the nasopharynx. Nine out of 10 ferrets infected with H3N2 subtype influenza A viruses developed either sinusitis or otitis media, while only 1 out of 11 ferrets infected with either an H1N1 influenza A virus or an influenza B virus did so. These data may partially explain why bacterial complication rates are higher during seasons when H3N2 viruses predominate. This animal model will be useful for further study of the mechanisms that underlie viral-bacterial synergism.

**Descriptors:** ferrets, bacterial infection, virus infection, sinusitis, pneumonia, viral-bacterial synergism.

Raila, J., C. Gomez, and F.J. Schweigert (2002). **The ferret as a model for vitamin A metabolism in carnivores.** *Journal of Nutrition* 132(6 Suppl 2): 1787s-1789s. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Descriptors:** ferret metabolism, vitamin A, diet, kidney metabolism, liver metabolism, retinol binding proteins, animal models.

Ter Meulen, J., A.B.H. Bakker, E.N. Van Den Brink, G.J. Weverling, B.E.E. Martina, B.L. Haagmans, T. Kuiken, J. De Kruif, W. Preiser, W. Spaan, H.R. Gelderblom, J. Goudsmit, and A.D.M.E. Osterhaus (2004). **Human monoclonal antibody as prophylaxis for sars coronavirus infection in ferrets.** *Lancet* 363(9427): 2139-2141. ISSN: 0099-5355.

**Descriptors:** ferrets, SARS infection, coronavirus infection, human monoclonal antibody, prophylaxis, severe acute respiratory syndrome, animal model.

von Messling, V., C. Springfield, P. Devaux, and R. Cattaneo (2003). **A ferret model of canine distemper virus virulence and immunosuppression.** *Journal of Virology* 77(23): 12579-12591. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** Canine distemper virus (CDV) infects many carnivores, including ferrets and dogs, and is the member of the Morbillivirus genus most easily amenable to experimentation in a homologous small-animal system. To gain insights into the determinants of CDV pathogenesis, we isolated a strain highly virulent for ferrets by repeated passaging in these animals. Sequence comparison of the genome of this strain with that of its highly attenuated precursor revealed 19 mutations distributed almost evenly in the six genes. We then recovered a virus from a cDNA copy of the virulent CDV strain's consensus sequence by using a modified reverse genetics system based on B cells. We infected ferrets with this virus and showed that it fully retained virulence as measured by the timing of rash appearance, disease onset, and death. Body temperature, leukocyte number, lymphocyte proliferation activity, and cell-associated viremia also had similar kinetics. We then addressed the question of the relative importance of the envelope and other viral constituents for virulence. Viruses in which the envelope genes (matrix, fusion, and hemagglutinin) of the virulent strain were combined with the other genes of the attenuated strain caused severe rash and fever even if the disease onset was delayed. Viruses in which the nucleocapsid, polymerase, and phosphoprotein genes (coding also for the V and C proteins) of the virulent strain were combined with the envelope genes of the attenuated strain caused milder signs of disease. Thus, virulence-inducing mutations have accumulated throughout the genome.

**Descriptors:** ferrets, animal disease models, distemper virus, canine pathogenicity, immunosuppression, b lymphocytes immunology, DNA, canine genetics, vero cells, virulence genetics.

von Messling, V., C. Springfield, P. Devaux, and R. Cattaneo (2003). **A ferret model of canine distemper virus virulence and immunosuppression.** *Journal of Virology* 77(23): 12579-12591. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Descriptors:** ferret, animal model, canine distemper, virulence, immunosuppression, Morbillivirus.

Wang, X.D. (2005). **Can smoke-exposed ferrets be utilized to unravel the mechanisms of action of lycopene.** *Journal of Nutrition* 135(8): 2053S-2056S. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Descriptors:** tomato products, lycopene, anticarcinogenic activity, lung cancer, ferrets, animal models, smoking habit, mechanism of action, dosage, metabolites, blood chemistry, lungs, cell proliferation, epidemiology.

**Notes:** In the special section: "Promises and perils of lycopene/tomato supplementation and cancer prevention." Presented at a conference held February 17-18, 2005, Bethesda, Maryland.

Wolf, G. (2002). **The effect of low and high doses of beta-carotene and exposure to cigarette smoking on the lungs of ferrets.** *Nutrition Reviews* 60(3): 88-90. ISSN: 0029-6643.

**NAL Call Number:** 389.8 N953

**Abstract:** When the diets of ferrets were supplemented with large (pharmacologic) daily doses of beta-carotene (BC) for 6 months, the levels of retinoic acid and the retinoic acid receptor beta declined significantly in lung tissues. Indicators of cell proliferation (c-jun and c-fos proteins and others) increased. Histologic observations showed that feeding high doses of BC resulted in keratinized squamous metaplasia in the lung tissues. When high-doses of BC were combined with daily exposure to cigarette smoke, the BC effects were greatly accentuated. These results may lead to an explanation of the increased incidence of lung cancer in two large independent epidemiologic studies of smokers in which pharmacologic doses of BC were given.

**Descriptors:** beta carotene, tobacco smoking, passive smoking, lungs, animal tissues, receptors, vitamin supplements, ferrets, literature reviews, lung tissues.

Woods, J.B., C.K. Schmitt, S.C. Darnell, K.C. Meysick, and A. O'Brien (2002). **Ferrets as a model system for renal disease secondary to intestinal infection with *Escherichia coli* O157:H7 and other Shiga toxin-producing *E. coli*.** *Journal of Infectious Diseases* 185(4): 550-554. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** Ferrets were evaluated as a possible small animal model for the development of colitis and/or signs of the hemolytic uremic syndrome after oral infection with *Escherichia coli* O157:H7 or other Shiga toxin--producing *E. coli* (STEC). Ferrets treated with streptomycin (Stm) had higher counts of *E. coli* O157:H7 strain 86-24 Stm-resistant (Stm(r)) or O91:H21 strain B2F1 Stm(r) in their stools than non--Stm-treated animals. None of the animals displayed evidence of colitis, but Stm-treated animals fed strain 86-24 Stm(r) exhibited weight loss significantly greater than that exhibited by ferrets fed an isogenic mutant negative for the adhesin intimin. Moreover, 11 (23%) of the 47 Stm-treated ferrets inoculated with 86-24 Stm(r) or B2F1 Stm(r) developed hematuria and/or histological damage to glomeruli or thrombocytopenia, compared with 0 of 14 uninfected control animals receiving Stm in water. Thus, the ferret may serve as a model for renal disease secondary to intestinal infection with STEC.

**Descriptors:** ferrets, animal disease models, *Escherichia coli* infections, *Escherichia coli* o157 pathogenicity, *Escherichia coli* proteins, intestinal diseases, kidney diseases, shiga toxin, intestinal diseases, streptomycin .

Zitzow, L.A., T. Rowe, T. Morken, W.J. Shieh, S. Zaki, and J.M. Katz (2002). **Pathogenesis of avian influenza A (H5N1) viruses in ferrets.** *Journal of Virology* 76(9): 4420-4429. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** Highly pathogenic avian influenza A H5N1 viruses caused outbreaks of disease in domestic poultry and humans in Hong Kong in 1997. Direct transmission of the H5N1 viruses from birds to humans resulted in 18 documented cases of respiratory illness, including six deaths. Here we evaluated two of the avian H5N1 viruses isolated from humans for their ability to replicate and cause disease in outbred ferrets. A/Hong Kong/483/97 virus was isolated from a fatal case and was highly pathogenic in the BALB/c mouse model, whereas A/Hong Kong/486/97 virus was isolated from a case with mild illness and exhibited a low-pathogenicity phenotype in mice. Ferrets infected intranasally with 10(7) 50% egg infectious doses (EID(50)) of either H5N1 virus exhibited severe lethargy, fever, weight loss, transient lymphopenia, and replication in the upper and lower respiratory tract, as well as multiple systemic organs, including the brain. Gastrointestinal symptoms were seen in some animals. In contrast, weight loss and severe lethargy were not noted in ferrets infected with 10(7) EID(50) of two recent human H3N2 viruses, although these viruses were also isolated from the brains, but not other extrapulmonary organs, of infected animals. The results demonstrate that both H5N1 viruses were highly virulent in the outbred ferret model, unlike the differential pathogenicity documented in

inbred BALB/c mice. We propose the ferret as an alternative model system for the study of these highly pathogenic avian viruses.

**Descriptors:** disease models, ferrets, influenza physiopathology, influenza A virus, avian pathogenicity, adolescent, child, influenza pathology and virology, lung pathology and virology, virulence, virus replication.

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## Information Resources on the Care and Welfare of Ferrets

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### Auditory / Hearing

Bizley, J.K., I. Nelken, F.R. Nodal, B. Ahmed, A.J. King, and J.W.H. Schnupp (2002). **An investigation into the functional anatomy of ferret auditory cortex using optical imaging and multi - electrode recordings.** In: *32nd Annual Meeting of the Society for Neuroscience, Society for Neuroscience Abstract Viewer and Itinerary Planner., November 2, 2002-November 7, 2002, Orlando, Florida, USA., Vol. 2002, p. Abstract No. 354.10.*

**Descriptors:** auditory cortex, functional anatomy, ferret, optical imaging, area mapping, recordings, auditory stimuli, frequency tuning.

Bizley, J.K., F.R. Nodal, I. Nelken, and A.J. King (2005). **Functional organization of ferret auditory cortex.** *Cerebral Cortex* 15(10): 1637-1653. ISSN: 1047-3211.

**Abstract:** We characterized the functional organization of different fields within the auditory cortex of anaesthetized ferrets. As previously reported, the primary auditory cortex, A1, and the anterior auditory field, AAF, are located on the middle ectosylvian gyrus. These areas exhibited a similar tonotopic organization, with high frequencies represented at the dorsal tip of the gyrus and low frequencies more ventrally, but differed in that AAF neurons had shorter response latencies than those in A1. On the basis of differences in frequency selectivity, temporal response properties and thresholds, we identified four more, previously undescribed fields. Two of these are located on the posterior ectosylvian gyrus and were tonotopically organized. Neurons in these areas responded robustly to tones, but had longer latencies, more sustained responses and a higher incidence of non-monotonic rate-level functions than those in the primary fields. Two further auditory fields, which were not tonotopically organized, were found on the anterior ectosylvian gyrus. Neurons in the more dorsal anterior area gave short-latency, transient responses to tones and were generally broadly tuned with a preference for high (>8 kHz) frequencies. Neurons in the other anterior area were frequently unresponsive to tones, but often responded vigorously to broadband noise. The presence of both tonotopic and non-tonotopic auditory cortical fields indicates that the organization of ferret auditory cortex is comparable to that seen in other mammals.

**Descriptors:** ferrets, auditory cortex, acoustic stimulation, brain mapping, electrodes, implanted, electroencephalography, neurons physiology.

Bizley, J.K., F.R. Nodal, C.H. Parsons, and A.J. King (2003). **Investigating the role of ferret primary auditory cortex in vertical sound localization using reversible inactivation and lesions.** *Society for Neuroscience Abstract Viewer and Itinerary Planner* 2003: Abstract No. 488.1.

**Descriptors:** ferret, primary auditory cortex, lesions, sound localization, broadband noise, vertical sound localization.

**Notes:** 33rd Annual Meeting of the Society of Neuroscience, New Orleans, LA, USA; November 08-12, 2003.

Campbell, R.A., J.W. Schnupp, A. Shial, and A.J. King (2006). **Binaural-level functions in ferret auditory cortex: Evidence for a continuous distribution of response properties.** *Journal of Neurophysiology* 95(6): 3742-3755. ISSN: 0022-3077.

**Abstract:** Many previous studies have subdivided auditory neurons into a number of physiological classes according to various criteria applied to their binaural response properties. However, it is often unclear whether

such classifications represent discrete classes of neurons or whether they merely reflect a potentially convenient but ultimately arbitrary partitioning of a continuous underlying distribution of response properties. In this study we recorded the binaural response properties of 310 units in the auditory cortex of anesthetized ferrets, using an extensive range of interaural level differences (ILDs) and average binaural levels (ABLs). Most recordings were from primary auditory fields on the middle ectosylvian gyrus and from neurons with characteristic frequencies  $>5$  kHz. We used simple multivariate statistics to quantify a fundamental coding feature: the shapes of the binaural response functions. The shapes of all 310 binaural response surfaces were represented as points in a five-dimensional principal component space. This space captured the underlying shape of all the binaural response surfaces. The distribution of binaural level functions was not homogeneous because some shapes were more common than others. Despite this, clustering validation techniques revealed no evidence for the existence of discrete, or partially overlapping, clusters that could serve as a basis for an objective classification of binaural-level functions. We also examined the gradients of the response functions for the population of units; these gradients were greatest near the midline, which is consistent with free-field data showing that cortical neurons are most sensitive to changes in stimulus location in this region of space.

**Descriptors:** ferrets, auditory perception, physiology, auditory threshold physiology, physiology, animal models, acoustic stimulation, methods, auditory cortex.

Moore, D.R., L.R. Highton, O. Kacelnik, and A.J. King (2002). **Effect of bilateral auditory cortex lesions on sound localisation by the ferret.** *Society for Neuroscience Abstract Viewer and Itinerary Planner 2002*: Abstract No. 845.11.

**Descriptors:** ferret, sound localisation, cortex lesion, surgical ablation, auditory cortex, motor problem, lesions, sensory deficit.

**Notes:** 32nd Annual Meeting of the Society for Neuroscience, Orlando, Florida, USA; November 02-07, 2002.

Mrsic Flogel, T.D., A.J. King, and J.W. Schnupp (2005). **Encoding of virtual acoustic space stimuli by neurons in ferret primary auditory cortex.** *Journal of Neurophysiology* 93(6): 3489-3503. ISSN: 0022-3077.

**Abstract:** Recent studies from our laboratory have indicated that the spatial response fields (SRFs) of neurons in the ferret primary auditory cortex (A1) with best frequencies  $>$  or  $=4$  kHz may arise from a largely linear processing of binaural level and spectral localization cues. Here we extend this analysis to investigate how well the linear model can predict the SRFs of neurons with different binaural response properties and the manner in which SRFs change with increases in sound level. We also consider whether temporal features of the response (e.g., response latency) vary with sound direction and whether such variations can be explained by linear processing. In keeping with previous studies, we show that A1 SRFs, which we measured with individualized virtual acoustic space stimuli, expand and shift in direction with increasing sound level. We found that these changes are, in most cases, in good agreement with predictions from a linear threshold model. However, changes in spatial tuning with increasing sound level were generally less well predicted for neurons whose binaural frequency-time receptive field (FTRF) exhibited strong excitatory inputs from both ears than for those in which the binaural FTRF revealed either a predominantly inhibitory effect or no clear contribution from the ipsilateral ear. Finally, we found (in agreement with other authors) that many A1 neurons exhibit systematic response latency shifts as a function of sound-source direction, although these temporal details could usually not be predicted from the neuron's binaural FTRF.

**Descriptors:** ferrets, auditory cortex, sound localization, space perception, acoustic stimulation, auditory pathways, radiation, animal models, neurological, predictive value of tests.

Mrsic Flogel, T.D., H. Versnel, and A.J. King (2006). **Development of contralateral and ipsilateral frequency representations in ferret primary auditory cortex.** *European Journal of Neuroscience* 23(3): 780-792. ISSN: 0953-816X.

**Abstract:** Little is known about the maturation of functional maps in the primary auditory cortex (A1) after the onset of sensory experience. We used intrinsic signal imaging to examine the development of the tonotopic organization of ferret A1 with respect to contralateral and ipsilateral tone stimulation. Sound-evoked responses were recorded as early as postnatal day (P) 33, a few days after hearing onset. From P36 onwards, pure tone stimuli evoked restricted, tonotopically organized patches of activity. There was an age-dependent increase in the cortical area representing each octave, with a disproportionate expansion of cortical territory representing frequencies  $> 4$  kHz after P60. Similar tonotopic maps were observed following stimulation of the contralateral

and ipsilateral ears. During the first few weeks following hearing onset, no differences were found in the area of cortical activation or in the magnitude of the optical responses evoked by stimulation of each ear. In older animals, however, contralateral stimuli evoked stronger responses and activated a larger A1 area than ipsilateral stimuli. Our findings indicate that neither the tonotopic organization nor the representation of inputs from each ear reach maturity until approximately 1 month after hearing onset. These results have important implications for cortical signal processing in juvenile animals.

**Descriptors:** ferrets, auditory cortex, brain mapping, sound localization, acoustic stimulation, age factors, diagnostic imaging, radiation, imaging, three dimensional methods.

Nelken, I., J.K. Bizley, F.R. Nodal, B. Ahmed, J.W. Schnupp, and A.J. King (2004). **Large-scale organization of ferret auditory cortex revealed using continuous acquisition of intrinsic optical signals.** *Journal of Neurophysiology* 92(4): 2574-2588. ISSN: 0022-3077.

**Abstract:** We have adapted a new approach for intrinsic optical imaging, in which images were acquired continuously while stimuli were delivered in a series of continually repeated sequences, to provide the first demonstration of the large-scale tonotopic organization of both primary and nonprimary areas of the ferret auditory cortex. Optical responses were collected during continuous stimulation by repeated sequences of sounds with varying frequency. The optical signal was averaged as a function of time during the sequence, to produce reflectance modulation functions (RMFs). We examined the stability and properties of the RMFs and show that their zero-crossing points provide the best temporal reference points for quantifying the relationship between the stimulus parameter values and optical responses. Sequences of different duration and direction of frequency change gave rise to comparable results, although in some cases discrepancies were observed, mostly between upward- and downward-frequency sequences. We demonstrated frequency maps, consistent with previous data, in primary auditory cortex and in the anterior auditory field, which were verified with electrophysiological recordings. In addition to these tonotopic gradients, we demonstrated at least 2 new acoustically responsive areas on the anterior and posterior ectosylvian gyri, which have not previously been described. Although responsive to pure tones, these areas exhibit less tonotopic order than the primary fields.

**Descriptors:** ferrets, auditory cortex, acoustic stimulation, brain mapping, electrodes implanted, electrophysiology, image processing, computer assisted, neurological, nerve net, respiratory mechanics, stereotaxic techniques.

Schnupp, J.W., J. Booth, and A.J. King (2003). **Modeling individual differences in ferret external ear transfer functions.** *Journal of the Acoustical Society of America* 113(4 Pt 1): 2021-2030. ISSN: 0001-4966.

**Abstract:** Individual variations in head and outer ear size, as well as growth of these structures during development, can markedly alter the values of the binaural and monaural cues which form the basis for auditory localization. This study investigated individual differences in the directional component of the head-related transfer function of both adult and juvenile ferrets. In line with previous studies in humans and cats, intersubject spectral differences were found to be reduced by scaling one of the directional transfer functions on a log-frequency axis. The optimal scale factor correlated most highly with pinna cavity height. Optimal frequency scaling reduced interear spectral difference equally well for adult-juvenile comparisons as for comparisons between pairs of adult ears. This illustrates that the developmental changes in localization cue values should be at least partly predictable on the basis of the expected growth rate of the outer ear structures. Predictions of interaural time differences (ITDs) were also derived from the physical dimensions of the head. ITDs were found to be poorly fitted by the spherical head model, while much better predictions could be derived from a model based on von Mises spherical basis functions. Together, these findings show how more accurate estimates of spatial cue values can be made from knowledge of the dimensions of the head and outer ears, and may facilitate the generation of virtual acoustic space stimuli in the absence of acoustical measurements from individual subjects.

**Descriptors:** ferrets, ear, external physiology, ferrets, laterality, sound localization, age factors, biometry, computer simulation, sound spectrography.

Versnel, H., J.E. Mossop, T.D. Mrcic Flogel, B. Ahmed, and D.R. Moore (2002). **Optical imaging of intrinsic signals in ferret auditory cortex: Responses to narrowband sound stimuli.** *Journal of Neurophysiology* 88(3): 1545-1558. ISSN: 0022-3077.

**Abstract:** This paper describes optical imaging of the auditory cortex in the anesthetized ferret, particularly

addressing optimization of narrowband stimuli. The types of sound stimuli used were tone-pip trains and sinusoidal frequency and amplitude modulated (SFM and SAM) tones. By employing short illumination wavelengths (546 nm), we have successfully characterized the tonotopic arrangement, in agreement with the well-established electrophysiological tonotopic maps of the ferret auditory primary field (AI). The magnitude of the optical signal increased with sound level, was maximal for a modulation frequency (MF) of 2-4 Hz, and was larger for tone-pip trains and SFM sounds than for SAM sounds. Accordingly, an optimal narrowband stimulus was defined. Thus optical imaging can be used successfully to obtain frequency maps in auditory cortex by an appropriate choice of stimulus parameters. In addition, background noise consisting of 0.1-Hz oscillations could be reduced by introduction of blood pressure enhancing drugs. The optical maps were largely independent of 1) the type of narrowband stimulus, 2) the sound level, and 3) the MF. This stability of the optical maps was not predicted from the electrophysiological literature.

**Descriptors:** ferrets, auditory cortex, acoustic stimulation, angiotensin II, brain mapping, optics, oscillometry, time factors, vasoconstrictor agents, vasomotor system.

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## Information Resources on the Care and Welfare of Ferrets

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### Biology

Christensson, M. and M. Garwicz (2005). **Time course of postnatal motor development in ferrets: Ontogenetic and comparative perspectives.** *Behavioural Brain Research* 158(2): 231-242. ISSN: 0166-4328.

**Descriptors:** ferrets, postnatal motor development, motor behavior, rats, experimental animals, comparative study.

He, T. and S. Kiliaridis (2004). **Craniofacial growth in the ferret (*Mustela putorius furo*)--a cephalometric study.** *Archives of Oral Biology* 49(10): 837-848. ISSN: 0003-9969.

**NAL Call Number:** RK1.A6989

**Abstract:** OBJECTIVE: When suggesting the ferret as a valid laboratory model in craniofacial research, it is essential to know about its normal craniofacial growth. DESIGN: Sixteen ferret kits (eight male and eight female) were selected for the present investigation. Serial lateral and dorsoventral cephalograms were taken on each animal at a mean age of 25, 35, 55, 80 and 300 days. The cephalograms were then digitised and the coordinates of 33 landmarks were derived on each set of cephalograms. Thirty-four variables were then calculated on each set of cephalograms by computer image programs with the coordinate data. Results were analysed statistically, and the craniofacial growth pattern and related sexual dimorphism were described in three perspectives: lateral and dorsoventral viscerocranium and neurocranium, and lateral mandible. FINDINGS: In both sexes, the viscerocranium and neurocranium follow an orderly pattern of expansive growth in three dimensions. The growth of the mandible is mainly characterised by an anteroposterior elongation of the mandibular body, an enlargement of the coronoid process, and an increase in height of the alveolar process. The growth rate varies with site. Craniofacial growth in ferrets starts to slow down and finally ceases earlier in female than in male animals.

**Descriptors:** ferrets, craniofacial growth, maxillofacial development, physiology, skull growth and development, cephalometry, mandible growth, sex factors, skull radiography.

He, T. and S. Kiliaridis (2003). **Effects of masticatory muscle function on craniofacial morphology in growing ferrets (*Mustela putorius furo*).** *European Journal of Oral Sciences* 111(6): 510-517. ISSN: 0909-8836.

**Abstract:** Studying the effects of masticatory muscle function on craniofacial morphology in animal models with different masticatory systems is important for further understanding of related issues in humans. Forty 5-wk-old male ferrets were equally divided into two groups. One group was fed a diet of hard pellets (HDG) and the other group was fed the same diet but softened with water (SDG). Lateral and dorsoventral cephalograms were taken on each group after 6 months. Cephalometric measurements were performed by digital procedures. For SDG ferrets, the hard palate plane was more distant from the cranial base plane, and canines were more proclined compared with HDG ferrets. The SDG ferrets were also found to have smaller interfrontal and interparietal widths, and a slenderer zygomatic arch than the HDG ferrets. In the mandible, the coronoid process was generally shorter and narrower for the SDG ferrets. The effects of the altered masticatory muscle function on craniofacial morphology in growing ferrets seemed to differ from those previously reported in other animal models studied under similar experimental conditions. Such differences in the effects are presumably related to the differences in the mode of mastication, craniofacial anatomy and growth pattern in different animal models.

**Descriptors:** ferret growth and development, mastication, masticatory muscles, maxillofacial development, skull growth and development, feed, nutrition, facial bones, mandible.

Hoefer, H.L. (2004). **The biology and husbandry of the pet ferret.** In: *Small animal and exotics Book two: Pain management zoonosis Proceedings of the North American Veterinary Conference., January 17, 2004-January 21, 2004, Orlando, Florida, USA.*, Eastern States Veterinary Association: Gainesville, USA, Vol. 18, p. 1383-1384.

**Descriptors:** ferrets, behavior, housing, husbandry, nutrition, clinical examination, diet, Mustela.

Marini, R.P., G. Otto, S. Erdman, L. Palley and J.G. Fox (2002). **Biology and diseases of ferrets.** In: J.G. Fox, L.C. Anderson, F.M. Loew and F.W. Quimby (Editors), *Laboratory Animal Medicine*, 2nd edition, Academic Press: London, UK, p. 483-517. ISBN: 0122639510.

**Descriptors:** ferrets, diseases, biology, parasites.

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# Blackfooted Ferrets

Title

### GENERAL

Branvold, H.A., D.E. Biggins, and J.H. Wimsatt (2003). **Photoperiod manipulation to increase the productivity of black-footed ferrets (*Mustela nigripes*) and Siberian polecats (*M. eversmanii*).** *Zoo Biology* 22(1): 1-14. ISSN: 0733-3188.

**NAL Call Number:** QL77.5.Z6

**Descriptors:** *Mustela nigripes*, *Mustela*, animal reproduction, endangered species, photoperiod, photoperiodism, lighting, breeding season, animal housing, artificial insemination, estrus, estrus synchronization, birth rate, females, males, animal breeding, *Mustela eversmanii*.

Burns, R., E.S. Williams, D. O'Toole, and J.P. Dubey (2003). ***Toxoplasma gondii* infections in captive black-footed ferrets (*Mustela nigripes*), 1992-1998: Clinical signs, serology, pathology, and prevention.** *Journal of Wildlife Diseases* 39(4): 787-797. ISSN: 0090-3558.

**NAL Call Number:** 41.9 W648

**Abstract:** An epizootic of toxoplasmosis occurred among 22 adult and 30 kit black-footed ferrets (*Mustela nigripes*) maintained under quarantine conditions at the Louisville Zoological Garden (Louisville, Kentucky, USA) in June, 1992. Black-footed ferrets appear to be highly susceptible to acute and chronic toxoplasmosis. Clinical signs were observed in 19 adults and six kits and included anorexia, lethargy, corneal edema, and ataxia. Two adults and six kits died with acute disease. High antibody titers to *Toxoplasma gondii* were detected by latex agglutination and modified agglutination assay in 10 black-footed ferrets. One adult and six kits that died with acute clinical signs were necropsied and *T. gondii*-like organisms were found microscopically in multiple organs. Diagnosis of toxoplasmosis was confirmed by immunohistochemical staining with anti-*T. gondii* antibodies and by ultrastructural examination. Although the source of *T. gondii* for black-footed ferrets was not identified, frozen uncooked rabbit was the most likely source. Chronic toxoplasmosis resulted in the death of an additional 13 black-footed ferrets that were adults during the epizootic. Affected animals developed chronic progressive posterior weakness and posterior ataxia 6-69 mo after the epizootic began. Meningoencephalitis or meningoencephalomyelitis associated with chronic toxoplasmosis were identified at necropsy in all 13 ferrets. Precautions to prevent introduction of pathogens into the colony were insufficient to exclude *T. gondii*. Although toxoplasmosis may cause significant mortality in mustelids, the high mortality of black-footed ferrets in this epizootic was of concern due to their endangered status. This is the first detailed report of toxoplasmosis in black-footed ferrets.

**Descriptors:** ferrets, antibodies, blood protozoan, toxoplasmosis, agglutination tests, immunohistochemistry, Kentucky, latex fixation tests, liver parasitology.

Lair, S., I.K. Barker, K.G. Mehren, and E.S. Williams (2006). **Renal Tubular-cell Neoplasms in Black-footed Ferrets (*Mustela nigripes*)-38 Cases.** *Veterinary Pathology* 43(3): 276-280. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Thirty-eight cases of renal tubular cell neoplasms were diagnosed in 184 captive, adult (>1-year-old), black-footed ferrets (*Mustela nigripes*) examined from 1985 to 1996. This prevalence (20.7%) is one of the highest reported for this neoplasm in a population of animals. These tumors rarely metastasized (1/38), and usually were incidental postmortem findings, associated clinical disease being present in only 3 (8%) of the 38 cases. The prevalence of renal tubular cell neoplasms found at postmortem examination increased linearly with age, up to 67% in ferrets >8 years old. Both males (prevalence = 19%) and females (prevalence = 24%) were affected. Multiple renal tumors were common, and seven ferrets (18.4% of affected animals) had bilateral tumors. The cause of this neoplastic syndrome could not be determined. Since most of the animals affected by this condition were in their postreproductive years of life, the impact of this neoplastic syndrome on the captive propagation of this species is negligible.

**Descriptors:** *Mustela nigripes*, kidney diseases, neoplasms, animal age, disease prevalence, disease course, zoo animals, endangered species.

Lair, S., I.K. Barker, K.G. Mehren, and E.S. Williams (2002). **Epidemiology of neoplasia in captive black-footed ferrets (*Mustela nigripes*), 1986-1996.** *Journal of Zoo and Wildlife Medicine* 33(3): 204-223. ISSN: 1042-7260.

**NAL Call Number:** SF601.J6

**Abstract:** The epidemiology of neoplastic disease was studied retrospectively in the captive population of black-footed ferrets (*Mustela nigripes*). Postmortem reports were reviewed and archived tissues examined from 184 of the 227 adult (>1 yr old) black-footed ferrets that died from the beginning of the current captive propagation program in late 1985 to the end of 1996. A total of 185 neoplasms, of 28 distinct phenotypes, were seen in 102 (55.4%) of these ferrets. There was more than one tumor type present in 51 ferrets. Tumors of the apocrine glands (28.3%), renal tubular neoplasms (20.7%), and biliary cystadenoma or carcinoma (20.1%) were the most common neoplasms. The probability of developing most types of neoplasms increased with age. Neoplasms of the apocrine glands were more common in males and may be hormonally influenced. The unusually high prevalence of biliary cystadenocarcinoma may be secondary to the common occurrence of intrahepatic biliary cysts in this population. Although neoplasia is an important cause of mortality in captive adult black-footed ferrets, its impact on captive propagation of the species, and on the wild population, is probably limited because clinically significant tumors are encountered almost exclusively in postreproductive ferrets (>3 yr old) and because ferrets released into their natural habitat rarely reach susceptible age.

**Descriptors:** black-footed ferrets, neoplasms, age distribution, logistic models, neoplasms classification and epidemiology, prevalence, retrospective studies, Wyoming, epidemiology.

Naples, V.L. (2005). **Locomotor specializations in the hindlimb of the black-footed ferret (*Mustela nigripes*): Adaptation to a subterranean habitat.** *FASEB Journal* 19(5, Suppl. S, Part 2): A1360. ISSN: 0892-6638.

**Descriptors:** *Mustela nigripes*, black-footed ferrets, muscular system, locomotor specializations in hindlimbs, environmental adaptation, tunnel system.

**Notes:** Experimental Biology 2005 Meeting/35th International Congress of Physiological Sciences, San Diego, CA, USA; March 31 -April 06, 2005.

Rocke, T.E., J. Mencher, S.R. Smith, A.M. Friedlander, G.P. Andrews, and L.A. Baeten (2004). **Recombinant F1-V fusion protein protects black-footed ferrets (*Mustela nigripes*) against virulent *Yersinia pestis* infection.** *Journal of Zoo and Wildlife Medicine* 35(2): 142-146. ISSN: 1042-7260.

**NAL Call Number:** SF601.J6

**Descriptors:** *Mustela nigripes*, black-footed ferrets, sylvatic plague, bacterial diseases, treatment techniques, recombinant protein vaccine, *Yersinia pestis*, vaccine challenges.

Rose, M., T. White, and G. Wadsworth (2002). **Phylogenetics of ancestral and extant populations of black-footed ferrets (*Mustela nigripes*).** *AAAS Annual Meeting and Science Innovation Exposition* 168: A97.

**Descriptors:** black-footed ferrets, phylogenetics, ancestral population, *Mustela nigripes*.

**Notes:** Annual Meeting of the American Association for the Advancement of Science, Boston, MA, USA; February 14-19, 2002.

Santymire, R.M., P.E. Marinari, J.S. Kreeger, D.E. Wildt, and J. Howard (2006). **Sperm viability in the black-footed ferret (*Mustela nigripes*) is influenced by seminal and medium osmolality.** *Cryobiology* 53(1): 37-50. ISSN: 0011-2240.

**Abstract:** Fundamental knowledge of spermatozoa cryobiology can assist with optimizing cryopreservation protocols needed for genetic management of the endangered black-footed ferret. Objectives were to characterize semen osmolality and assess the influence of two media at various osmolalities on sperm viability. We examined the influence of Ham's F10 +Hepes medium (H) at 270, 400, 500 or 700 mOsm (adjusted with sucrose, a nonpermeating cryoprotectant) and TEST Yolk Buffer (TYB) with 0% (300 mOsm) versus 4% (900 mOsm) glycerol (a permeating cryoprotectant). Electroejaculates (n=16) were assessed for osmolality using a vapor pressure osmometer. For media comparison, semen (n=5) was collected in TYB 0%, split into six aliquots, and diluted in H270, H400, H500, H700, and TYB 0% or TYB 4%. Each sample was centrifuged (300 g, 8 min), resuspended in respective medium, and maintained at 37 degrees C for 3h. Sperm motility and forward progression were monitored every 30 min for 3h post-washing. Acrosomal integrity was monitored at 0 and 60 min post-washing. Results demonstrated that black-footed ferret semen has a comparatively high osmolality (mean+/-SEM, 513.1+/-32.6 mOsm; range, 366-791 mOsm). Ferret spermatozoa were sensitive to hyperosmotic stress. Specifically, sperm motility was more susceptible (P<0.01) to hyperosmotic conditions than acrosomal integrity, and neither were influenced (P>0.05) by hypotonic solutions. Exposure to TYB 4% glycerol retained more (P<0.01) sperm motility than a hyperosmotic Ham's (700 mOsm). These findings will guide the eventual development of assisted breeding with cryopreserved sperm contributing to genetic management of this rare species.

**Descriptors:** ferrets, cell survival, drug effects, physiology, semen, preservation methods, spermatozoa physiology, glucose, pharmacology, osmolar concentration, sperm motility, drug effects, spermatozoa cytology.

Santymire, R.M., P.E. Marinari, J.S. Kreeger, D.E. Wildt, and J.G. Howard (2004). **Determining semen osmolality and effect of medium osmolality on sperm viability in the black-footed ferret (*Mustela nigripes*).** *Journal of Andrology*(Suppl. S): 91. ISSN: 0196-3635.

**Descriptors:** black-footed ferret, reproduction, semen osmolality, medium osmolality, sperm viability, meeting abstract.

**Notes:** 29th Annual Meeting of the American Society of Andrology, Baltimore, MD, USA; April 17-20, 2004.

Wisely, S.M., S.W. Buskirk, and M.A. Fleming (2002). **Genetic diversity and fitness in black-footed ferrets before and during a bottleneck.** *The Journal of Heredity* 93(4): 231-237. ISSN: 0022-1503.

**Abstract:** The black-footed ferret (*Mustela nigripes*) is an endangered North American carnivore that underwent a well-documented population bottleneck in the mid-1980s. To better understand the effects of a bottleneck on a free-ranging carnivore population, we used 24 microsatellite loci to compare genetic diversity before versus during the bottleneck, and compare the last wild population to two historical populations. We also compared genetic diversity in black-footed ferrets to that of two sibling species, the steppe polecat (*Mustela eversmanni*) and the European polecat (*Mustela putorius*). Black-footed ferrets during the bottleneck had less genetic diversity than steppe polecats. The three black-footed ferret populations were well differentiated ( $F_{ST} = 0.57$  [plus or minus] 0.15; mean [plus or minus] SE). We attributed the decrease in genetic diversity in black-footed ferrets to localized extinction of these genetically distinct subpopulations and to the bottleneck in the surviving subpopulation. Although genetic diversity decreased, female fecundity and juvenile survival were not affected by the population bottleneck. Reprinted by permission of the publisher.

**Descriptors:** black-footed ferrets, genetic diversity, bottleneck, population, free ranging.

Wisely, S.M., D.B. McDonald, and S.W. Buskirk (2003). **Evaluation of the genetic management of the endangered black-footed ferret (*Mustela nigripes*).** *Zoo Biology* 22(3): 287-298. ISSN: 0733-3188.

**NAL Call Number:** QL77.5.Z6

**Descriptors:** *Mustela nigripes*, endangered species, genetic variation, breeding methods, species reintroduction, microsatellite repeats, marker assisted selection, inbreeding, line differences, wildlife management, animal genetic resources, Montana, South Dakota, captive breeding.

Wisely, S.M., J.J. Ososky, and S.W. Buskirk (2002). **Morphological changes to black-footed ferrets (*Mustela nigripes*) resulting from captivity.** *Canadian Journal of Zoology* 80(9): 1562-1568. ISSN: 0008-4301.

**NAL Call Number:** 470 C16D

**Descriptors:** ferrets, skull, teeth, morphology, body measurements, variation, capture of animals, animal breeding, inbreeding depression, museum specimens, endangered species, wildlife conservation, craniometrics, skull size, captive breeding.

**Language of Text:** English; Summary in French.

Wisely, S.M., R.M. Santymire, T.M. Livieri, P.E. Marinari, J.S. Kreeger, D.E. Wildt, and J. Howard (2005).

**Environment influences morphology and development for in situ and ex situ populations of the black-footed ferret (*Mustela nigripes*).** *Animal Conservation* 8(Part 3): 321-328. ISSN: 1367-9430.

**Descriptors:** black-footed ferrets, wildlife conservation, in situ and ex situ populations of animals, environment influences on morphology and development, reintroduction programs.

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### Care / Housing

- Ball, R.S. (2002). **Husbandry and management of the domestic ferret.** *Lab Animal* 31(5): 37-42. ISSN: 0093-7355.  
**NAL Call Number:** QL55.A1L33  
**Descriptors:** ferrets, laboratory mammals, animal husbandry, animal welfare, odors, animal feeding, estrous cycle, estrus, ovulation, helicobacter, gastroenteritis, Aleutian disease, dirofilaria immitis, urinary calculi, urine pH, veterinary products, animal handling, induced ovulators.
- Bixler, H. and C. Ellis (2004). **Ferret care and husbandry.** *Veterinary Clinics of North America. Exotic Animal Practice* 7(2): 227-255, V. ISSN: 1094-9194.  
**NAL Call Number:** SF997.5.E95 E97  
**Abstract:** Convivial and playful, the ferret has cohabited with humans for hundreds of years. Maintenance of this mustelid's health and quality of life is paramount for the endurance of the human-animal bond. This review article for veterinary care givers, veterinarians, and staff, encompasses discussions on: husbandry, clinical techniques, prevalent diseases, history taking, physical examination, vaccination, and pain recognition. This article also enables the veterinary community to contribute to the care and welfare of ferret patients by offering facts to distinguish these animals from dogs and cats.  
**Descriptors:** animal husbandry, ferrets, care, welfare, clinical techniques, diseases, physical examination, vaccination, pain recognition.
- Hoefer, H.L. (2004). **The biology and husbandry of the pet ferret.** In: *Small animal and exotics Book two: Pain management zoonosis Proceedings of the North American Veterinary Conference., January 17, 2004-January 21, 2004, Orlando, Florida, USA.,* Eastern States Veterinary Association: Gainesville, USA, Vol. 18, p. 1383-1384.  
**Descriptors:** ferrets, behavior, housing, husbandry, nutrition, clinical examination, diet, Mustela.
- Reinhardt, V. and A. Reinhardt (2006). **Database on Refinement of Housing and Handling Conditions and Environmental Enrichment for Animals Kept in Laboratories: Rodents, Rabbits, Cats, Dogs, Ferrets, Farm Animals, Horses, Birds Fishes, Amphibians and Reptiles.,** [Online Database]  
**Online:** <http://labanimals.awionline.org/SearchResultsSite/refine.aspx>  
**NAL Call Number:** SF406.3  
**Descriptors:** laboratory animals housing databases, laboratory animals environmental enrichment databases, databases, enrichment, housing.
- Staton, V.W. and S.L. Crowell-Davis (2003). **Factors associated with aggression between pairs of domestic ferrets.** *Journal of the American Veterinary Medical Association* 222(12): 1709-1712.  
**Descriptors:** aggressive behavior, ferrets, familiarity, sex, neutering status, caging, time of year.

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### Circulatory / Cardiovascular

Bartunek, A.E., V.A. Claes, and P.R. Housmans (2002). **Effects of volatile anesthetics on elastic stiffness in isometrically contracting ferret ventricular myocardium.** *Journal of Applied Physiology* 92(6): 2491-2500. ISSN: 8750-7587.

**Abstract:** The effects of halothane, isoflurane, and sevoflurane on elastic stiffness, which reflects the degree of cross-bridge attachment, were studied in intact cardiac muscle. Electrically stimulated (0.25 Hz, 25[degree]C), isometrically twitching right ventricular ferret papillary muscles (n = 15) at optimal length (L<sub>max</sub>) were subjected to sinusoidal length oscillations (40 Hz, 0.25-0.50% of L<sub>max</sub> peak to peak). The amplitude and phase relationship with the resulting force oscillations was decomposed into elastic and viscous components of total stiffness in real time. Increasing extracellular Ca<sup>2+</sup> concentration in the presence of anesthetics to produce peak force equal to control increased elastic stiffness during relaxation, which suggests a direct effect of halothane and sevoflurane on cross bridges. Reprinted by permission of the publisher.

**Descriptors:** ferret, volatile anesthetics, ventricular myocardium, elastic stiffness, contracting, halothane, isoflurane, sevoflurane.

Brown, C. (2006). **Blood collection from the cranial vena cava of the ferret.** *Lab Animal* 35(9): 23-24. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Abstract:** The domestic ferret, though not as common a laboratory animal as the rat or mouse, serves as a model in critical research areas, including influenza biology and vaccine development. Studies involving ferrets necessitate knowledge of proper blood collection methods, such as cranial vena cava puncture.

**Descriptors:** ferret, blood collection, cranial vena cava, animal model, research.

Burattini, R. and K.B. Campbell (2002). **Comparative analysis of aortic impedance and wave reflection in ferrets and dogs.** *American Journal of Physiology* 282(1): H244-H255. ISSN: 0363-6135.

**Abstract:** Our modified version of the T-tube arterial model (consisting of two parallel, loss-free transmission paths terminating in lumped loads of complex and frequency-dependent nature) was applied to experimental measurements of ascending aortic pressure and of ascending and descending aortic flows taken from dogs and ferrets. Our aim was to provide quantitative evaluation of the aortic pressure and flow pulse wave components as they relate to the distribution of arterial properties and relate to wave travel and reflection in mammals of consistently different size and shape. Estimated effective lengths (distances to effective reflection sites) of the head-end (d(h)) and body-end (d(b)) transmission paths were approximately 12 and 30 cm, respectively, in the dog and 6.5 and 13 cm, respectively, in the ferret. These lengths and distributions of estimated arterial properties were consistent with the difference in the body size and with the more central location of the heart in the ferret's body than it is in the dog's body. In both animal species the ascending aortic pressure and flow waves could be interpreted in terms of forward and reflected components arising from the two distinct effective reflection sites, although the higher d(h)/d(b) ratio in the ferret determined the presence of one broad, indistinct minimum in the modulus of ascending aortic impedance in the frequency range from 0 to 10 Hz, rather than two distinct minima as observed in the dog.

**Descriptors:** ferrets, dogs, aorta physiology, blood flow velocity, electric impedance, aortic valve, blood pressure, elasticity, kinetics, animal models of cardiovascular disease, species specificity.

**Notes:** Erratum In: Am J Physiol Heart Circ Physiol 2002 Sep;283(3):following table of contents.

Diaz, M.E., D.a. Eisner, and a.W. Trafford (2002). **Changes in intracellular calcium handling in a ferret model of left ventricular hypertrophy and heart failure.** *Pflugers Archiv. European Journal of Physiology* 443(Supplement 1): S376-S377. ISSN: 0031-6768.

**Descriptors:** ferret model, heart failure, ventricular hypertrophy, calcium handling, intracellular, changes.

**Notes:** 81st Annual Joint Meeting of the Physiological Society, the Scandinavian Physiological Society and the German Physiological Society, Tuebingen, Germany; March 15-19, 2002.

Flatman, P.W. (2005). **Activation of ferret erythrocyte  $Na^{+}-K^{+}-2Cl^{-}$  cotransport by deoxygenation.** *The Journal of Physiology* 563(2): 421-431. ISSN: 0022-3751.

**NAL Call Number:** 447.8 J82

**Descriptors:** ferret, deoxygenation, kinase, phosphatase, magnesium.

Graham, H.K. and A.W. Trafford (2004). **Decreased heart rate variability in a ferret model of heart failure.** *Biophysical Journal* 86(1): 383a-384a. ISSN: 0006-3495.

**Descriptors:** ferret, animal model, heart failure, decreased heart rate, variability, cardiac arrhythmias, autonomic control.

**Notes:** 48th Annual Meeting of the Biophysical Society, Baltimore, MD, USA; February 14-18, 2004.

Johnson Delaney, C.A. (2005). **Ferret cardiopulmonary resuscitation.** *Seminars in Avian and Exotic Pet Medicine* 14(2): 135-142. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, cardiopulmonary resuscitation, therapy, heart diseases, reviews, techniques, cardiac massage, cardiac arrest.

Kottwitz, J.J., V. Luis Fuentes, and B. Micheal (2006). **Nonbacterial thrombotic endocarditis in a ferret (*Mustela putorius furo*).** *Journal of Zoo and Wildlife Medicine* 37(2): 197-201. ISSN: 1042-7260.

**NAL Call Number:** SF601.J6

**Descriptors:** ferret, thrombotic endocarditis, nonbacterial, pelvic limb ataxia, cardiac murmur, pathology, clinical aspects, diagnosis, endocarditis, histopathology, postmortem examinations.

Lowe, M.D., J.a. Lynham, A.a. Grace, and A.J. Kaumann (2002). **Comparison of the affinity of beta-blockers for two states of the beta1-adrenoceptor in ferret ventricular myocardium.** *British Journal of Pharmacology* 135(2): 451-461. ISSN: 0007-1188.

**Descriptors:** ferret, ventricular myocardium, beta blockers, affinity, betal andrenoceptor, comparison, potency, cardiostimulant effects.

McLain, D.E. (2006). **Use of an adjustable restraint device for prolonged and intermittent intravenous infusion and blood sampling in ferrets.** *Lab Animal* 35(7): 47-50. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Descriptors:** ferrets, restraint, instrumentation, blood specimen, collection, methods, infusions, intravenous, methods, infusions.

Sanchez Migallon Guzman, D., J. Mayer, R. Melidone, R. McCarthy J, E. McCobb, A. Kavirayani, and J. Rush E (2006). **Pacemaker implantation in a ferret (*Mustela putorius furo*) with third-degree atrioventricular block.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 677-687. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** A 7.5-year-old castrated male ferret (*Mustela putorius furo*) was diagnosed with third-degree atrioventricular (AV) block. A monopolar epicardial pacemaker system was implanted, resulting in a regular, paced cardiac rhythm with third-degree AV block at 140 beats per minute. Over the next 2 months, the ferret developed anorexia, interstitial pneumonia, intermittent diarrhea, and hind-limb weakness and had a slow and progressive recovery. The ferret developed clinical signs of congestive heart failure 4 months after the surgery,

resulting in its death 3 weeks later. Necropsy results attributed the death to cardiac failure due to extensive myocardial mineralization. To the authors' knowledge this is the first published report of surgical report of surgical pacemaker implantation in a ferret.

**Descriptors:** ferret, atrioventricular block, pacemaker, implantation, congestive heart failure, myocardial mineralization.

Vastenburger, M.H., S.A. Boroffka, and N.J. Schoemaker (2004). **Echocardiographic measurements in clinically healthy ferrets anesthetized with isoflurane.** *Veterinary Radiology & Ultrasound* 45(3): 228-232. ISSN: 1058-8183.

**NAL Call Number:** SF757.8.A4

**Abstract:** Two-dimensional, M4-mode, and color flow Doppler echocardiography was performed in 29 (18 females, 11 males) clinically healthy ferrets anesthetized with isoflurane. M-mode measurements of the left ventricle, left atrial appendage diameter (LAAD), and aorta (Ao) were obtained. The fractional shortening and LAAD/Ao ratio were calculated. The values of the M-mode measurements were compared between the male and female ferrets using a Student's t-test. No significant differences were found. The difference in body weight between the male and female ferrets was highly significant ( $P < 0.001$ ), but no significant correlation was found between body weight and M-mode measurements. Color flow Doppler examinations of the mitral, tricuspid, aortic, and pulmonary valves were recorded and there was minor valvular regurgitation in five ferrets, which was considered nonsignificant.

**Descriptors:** anesthesia, anesthetics, inhalation pharmacology, ferrets, heart ventricles, isoflurane, ultrasonography, reference values, doppler ultrasonography, echocardiography.

Zandvliet, M.M.a. (2005). **Electrocardiography in psittacine birds and ferrets.** *Seminars in Avian and Exotic Pet Medicine* 14(1): 34-51. ISSN: 1055-937X.

**Descriptors:** electrocardiography, ECG, psittacine, *Mustela furo*, cardiac disease, parrots, ferrets.

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### Dental

He, T., H. Friede, and S. Kiliaridis (2002). **Dental eruption and exfoliation chronology in the ferret (*Mustela putorius furo*)**. *Archives of Oral Biology* 47(8): 619-623. ISSN: 0003-9969.

**NAL Call Number:** RK1.A6989

**Abstract:** Substituting ferrets for rats and dogs as animal models for craniofacial research is favourable because of the similarity of many of the ferret's anatomical, metabolic and physiological features to those of man. Other advantages are cost-effectiveness and possibly less ethical controversy. However, information on the dental chronology of ferrets needs to be supplemented if this animal is to be promoted as an alternative model. Dental development was here examined in 16 ferrets (eight males, eight females) from three litters at between 12 and 90 days of age. Dental eruption and exfoliation were assessed and recorded every second day. The sequence of eruption of deciduous and permanent teeth was determined and data were analysed statistically. Also, any sex-related differences in eruption and exfoliation ages were defined. No deciduous incisors were observed to erupt in this group of animals. Other deciduous teeth erupted between the 19th and 31st postnatal days, and exfoliated between days 51 and 76. The time of eruption of the permanent teeth ranged from 42 to 77 days, in accordance with the stage of the mixed dentition. The female ferrets were generally ahead of the males in the exfoliation age of their deciduous teeth and the eruption age of their permanent teeth, but this, a sex difference did not apply to the eruption age of the deciduous teeth. These extended basic data might facilitate the introduction of this alternative experimental animal into craniofacial research.

**Descriptors:** ferrets physiology, animal models, tooth eruption physiology, tooth exfoliation, deciduous teeth, aging physiology, sex factors.

Takemura, A., I. Toda, H. Ike, M. Uemura, Y. Tamaada, and F. Suwa (2004). **SEM studies of the lingual papillae in the ferret (*Mustela putorius furo*)**. *Anatomical Science International* 79(August): 404. ISSN: 1447-6959.

**Descriptors:** ferret, lingual papillae, dental system, ingestion, imaging, microscopy techniques.

**Notes:** 16th International Congress of the IFAA (International Federation of Associations of Anatomists) and the 109th Annual Meeting of the Japanese Association of Anatomists, Kyoto, Japan; August 22-27, 2004.

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### Digestive System

Nagakura, Y., T. Kiso, K. Miyata, H. Ito, K. Iwaoka, and T. Yamaguchi (2002). **The effect of the selective 5-HT(3) receptor agonist on ferret gut motility.** *Life Sciences* 71(11): 1313-1319. ISSN: 0024-3205.

**Abstract:** The effect of the selective 5-hydroxytryptamine (5-HT)(3) receptor agonist YM-31636 (2-(1H-imidazol-4-ylmethyl)-8H-indeno[1,2-d]thiazole monofumarate) on gut motility of fed ferrets was investigated. YM-31636 (0.1 mg/kg p.o.) induced a giant migrating contraction (GMC)-like, high-amplitude, ungrouped colonic contraction although it did not change the basal colonic motility pattern. This GMC-like contraction was always accompanied by defecation. Both GMC-like contraction and defecation were inhibited with the selective 5-HT(3) receptor antagonist ramosetron. YM-31636 affected gastric, duodenal and ileal motility pattern only slightly. These results suggest that 5-HT(3) receptor agonists such as YM-31636 are useful in treating constipation since they facilitate GMC-like contractions and defecation without undesired changes in gut motility pattern.

**Descriptors:** ferrets, gastrointestinal motility, pyrroles, serotonin agonists, thiazoles, benzimidazoles, colon drug effects, defecation, gastrointestinal motility, muscle contraction, serotonin antagonists.

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### Diseases

- Allison, N. (2006). **Biliary cystadenomatosis in a ferret.** *Veterinary Medicine* 101(4): 199-200. ISSN: 8750-7943.  
**NAL Call Number:** 41.8 M69  
**Descriptors:** ferret, disease, biliary cystadenomatosis.
- Angella, P.R.A., K.A. Margit, and H. Gyula (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei -irodalmi attekintes 4. Endokrin eredetu bokelvaltozasok, hormonalis megbetegedések. [Reproduction, genital malfunctions and endocrine disorders of domestic ferrets (*Mustela putorius furo*): Literature review. 4. Endocrine skin lesions, hormonal diseases].** *Magyar Allatorvosok Lapja* 126(9): 553-560. ISSN: 0025-004X.  
**Descriptors:** endocrine system, tumor biology, endocrine disease, pathology, metabolic disease, adrenal, metabolic disease, epidemiology, neoplastic disease.  
**Language of Text:** Hungarian.
- Antinoff, N. and K. Hahn (2004). **Ferret oncology: Diseases, diagnostics, and therapeutics.** *Veterinary Clinics of North America. Exotic Animal Practice* 7(3): 579-625, Vi. ISSN: 1094-9194.  
**NAL Call Number:** SF997.5.E95 E97  
**Abstract:** Many standard diagnostic and chemotherapeutic protocols can be adapted for use in ferrets. Unique anatomic and clinical features dictate modification of protocols, but should not prohibit diagnosis or treatment. Ferrets may be the easiest of nontraditional species to treat with chemotherapeutics. We can provide more options for our patients, with improved quality of life and longer survival times than ever before. Although clients are never happy to hear the diagnosis of "cancer," it is no longer a word that condemns their beloved pet.  
**Descriptors:** ferrets, neoplasms, diagnosis, diseases, oncology, chemotherapeutics.
- Benoit Biancamano, M.O., M. Morin, and I. Langlois (2005). **Histopathologic lesions of diabetes mellitus in a domestic ferret.** *Canadian Veterinary Journal* 46(10): 895-897. ISSN: 0008-5286.  
**NAL Call Number:** 41.8 R3224  
**Descriptors:** ferrets, diabetes mellitus, animal diseases, histopathology, lesions animal, case studies, drug therapy, insulin, microscopy, fatty liver, islets of Langerhans, acidosis, ketones, pets, diet, breakfast cereals.  
**Language of Text:** English; Summary in French.
- Burns, R., E.S. Williams, D. O'Toole, and J.P. Dubey (2003). ***Toxoplasma gondii* infections in captive black-footed ferrets (*Mustela nigripes*), 1992-1998: Clinical signs, serology, pathology, and prevention.** *Journal of Wildlife Diseases* 39(4): 787-797. ISSN: 0090-3558.  
**NAL Call Number:** 41.9 W648  
**Abstract:** An epizootic of toxoplasmosis occurred among 22 adult and 30 kit black-footed ferrets (*Mustela nigripes*) maintained under quarantine conditions at the Louisville Zoological Garden (Louisville, Kentucky, USA) in June, 1992. Black-footed ferrets appear to be highly susceptible to acute and chronic toxoplasmosis. Clinical signs were observed in 19 adults and six kits and included anorexia, lethargy, corneal edema, and

ataxia. Two adults and six kits died with acute disease. High antibody titers to *Toxoplasma gondii* were detected by latex agglutination and modified agglutination assay in 10 black-footed ferrets. One adult and six kits that died with acute clinical signs were necropsied and *T. gondii*-like organisms were found microscopically in multiple organs. Diagnosis of toxoplasmosis was confirmed by immunohistochemical staining with anti-*T. gondii* antibodies and by ultrastructural examination. Although the source of *T. gondii* for black-footed ferrets was not identified, frozen uncooked rabbit was the most likely source. Chronic toxoplasmosis resulted in the death of an additional 13 black-footed ferrets that were adults during the epizootic. Affected animals developed chronic progressive posterior weakness and posterior ataxia 6-69 mo after the epizootic began.

Meningoencephalitis or meningoencephalomyelitis associated with chronic toxoplasmosis were identified at necropsy in all 13 ferrets. Precautions to prevent introduction of pathogens into the colony were insufficient to exclude *T. gondii*. Although toxoplasmosis may cause significant mortality in mustelids, the high mortality of black-footed ferrets in this epizootic was of concern due to their endangered status. This is the first detailed report of toxoplasmosis in black-footed ferrets.

**Descriptors:** ferrets, antibodies, blood protozoan, toxoplasmosis, agglutination tests, immunohistochemistry, Kentucky, latex fixation tests, liver parasitology.

Burr, D.H., D. Rollins, L.H. Lee, D.L. Pattarini, S.S. Walz, J.H. Tian, J.L. Pace, A.L. Bourgeois, and R.I. Walker (2005). **Prevention of disease in ferrets fed an inactivated whole cell *Campylobacter jejuni* vaccine.** *Vaccine* 23(34): 4315-4321. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Ferrets were used to demonstrate the potential of a killed whole cell vaccine prepared from *Campylobacter jejuni* to protect against disease. *C. jejuni* strain 81-176 was grown in BHI broth, formalin-fixed, and resuspended in PBS to a concentration of 10(10) cells per ml. This vaccine (CWC) or live organisms were delivered orally with a nasogastric tube into anesthetized animals treated to reduce gastric acidity and intestinal motility. When 5x10(10) CFU of the vaccine strain (Lior serotype 5) or one of two other serotypes, CGL-7 (Lior 4) or BT44 (Lior 9), was used to challenge the ferrets, all of the animals developed a mucoid diarrhea. If the animals had been challenged with 5x10(9) CFU of the homologous strain 1 month before challenge with 10(10) CFU, 80-100% protection against disease was seen. This protection was also obtained after an initial exposure to the 81-176 strain followed by challenge with either of the heterologous strains. CWC was used to see if protection demonstrated with the live organisms could be produced with the non-living preparation. When 10(9) cells of CWC was given as two doses 7 days apart with or without 25µg of a coadministered mucosal adjuvant, LT(R192G), only 40-60% of the animals were protected. If the regimen was changed to four doses given 48h apart, 80% of the animals were free of diarrhea after subsequent challenge. Increasing the number of cells in the four dose regimen to 10(10) cells did not improve protection. Animals given four doses of 10(10) cells combined with LT(R192G) were subsequently challenged with 10(10) cells of the homologous strain or the heterologous strain CGL-7. The CWC protected against both strains. Serum IgG antibody titers determined by ELISA showed little increase following the CWC four dose vaccination regimen, compared to animals given one dose of the live organism. On subsequent challenge, however, both CWC vaccinated and live-challenged ferrets showed comparable antibody titer increases above those obtained following the initial challenge or vaccination. Western blots were used to show that the immunodominant antigen in vaccinated animals was a 45kDa protein, while in ferrets challenged with live organisms the immunodominant antigen was a 62kDa protein. These data show that the CWC can be used to protect against disease caused by *Campylobacter*. They also show that protection and serum IgG responses do not depend upon the use of the mucosal adjuvant and that cross protection among some of the major serotypes of *Campylobacter* responsible for human disease is possible.

**Descriptors:** ferrets, bacterial vaccines, immunology, campylobacter infections, *Campylobacter jejuni*, immunoglobulin g, inactivated immunology.

Caley, P. and J. Hone (2005). **Assessing the host disease status of wildlife and the implications for disease control: *Mycobacterium bovis* infection in feral ferrets.** *Journal of Applied Ecology* 42(4): 708-719. ISSN: 0021-8901.  
**NAL Call Number:** 410 J828

**Descriptors:** feral ferrets, disease status, disease control, assessing, implications, *Mycobacterium bovis*.

Carmel, B. (2006). **Eosinophilic gastroenteritis in three ferrets.** *Veterinary Clinics of North America. Exotic Animal*

*Practice* 9(3): 707-712. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Eosinophilic gastroenteritis (EGE) is a rarely reported condition of ferrets. This article reviews three cases of suspected EGE in ferrets, summarizes the presenting signs, differential diagnoses, and treatment options, and discusses some question raised by this disease in ferrets. Immune suppression by means of prednisolone therapy is currently the treatment of choice.

**Descriptors:** Ferrets, eosinophilic gastroenteritis, signs, diagnosis, treatment.

Dalrymple, E.F. (2004). **Pregnancy toxemia in a ferret.** *Canadian Veterinary Journal* 45(2): 150-152. ISSN: 0008-5286.

**NAL Call Number:** 41.8 R3224

**Abstract:** A late-gestation jill was presented for depression, anorexia, and weakness. The working diagnosis became pregnancy toxemia. Supportive care was initiated and an emergency cesarian section performed. Twelve live kits were delivered; however, all soon perished despite home care. Surgery and recovery are discussed, including information regarding pregnancy toxemia in general.

**Descriptors:** ferrets, cesarean section, pre eclampsia, nutrition, newborn, diagnosis, differential, hysterectomy, ovariectomy, surgery, pregnancy outcome.

de Lisle, G.W., G.F. Yates, P. Caley, and R.J. Corboy (2005). **Surveillance of wildlife for *Mycobacterium bovis* infection using culture of pooled tissue samples from ferrets (*Mustela furo*).** *New Zealand Veterinary Journal* 53(1): 14-18. ISSN: 0048-0169.

**Abstract:** AIM: To compare culture results of homogenates of pooled lymph nodes from individual ferrets with and without macroscopic lesions of bovine tuberculosis for the presence of *Mycobacterium bovis*, and to determine whether homogenates from 10-30 ferrets could be combined and cultured without loss of sensitivity as a possible method for improving cost-effectiveness of surveillance for *M. bovis* infection in wildlife populations. METHODS: Numbers of colony forming units (cfu) of *M. bovis* present in cultures of homogenates of pooled lymph nodes from individual ferrets known to be infected and having no visible lesions (NVL) or macroscopic lesions consistent with bovine tuberculosis were determined. Prevalences of *M. bovis* infection in populations of ferrets in the Marlborough region of the South Island of New Zealand were determined by culturing homogenates of pooled lymph nodes from individual animals. Samples from homogenates from North Canterbury were combined to form pools representing 10, 20 and 30 animals and also cultured for *M. bovis*. RESULTS: Fewer *M. bovis* cfu were isolated from ferrets with NVL (mean=0.77 log<sub>10</sub>) compared with ferrets with macroscopic lesions (mean=3.22 log<sub>10</sub>; p<0.05). The mean prevalence of infection in eight different surveys involving 427 ferrets from the Marlborough region was 18% (range 8-44%), which included a small number of animals with macroscopic lesions of tuberculosis. Pooling of samples from up to 30 different ferrets with NVL did not reduce the sensitivity of detecting *M. bovis* infected populations.

CONCLUSION: Culturing of pools of lymph node samples detected a significant proportion of *M. bovis*-infected ferrets that would otherwise have gone unnoticed based on samples that had only macroscopic lesions. Culturing of samples pooled from up to 30 different ferrets could provide significant cost savings in surveys of wildlife for the presence of *M. bovis* infection without any apparent loss of sensitivity.

**Descriptors:** bacteriological techniques, ferrets, *Mycobacterium bovis*, tuberculosis, wild animals, New Zealand, population surveillance, predictive value of tests.

Garcia, A., S.E. Erdman, S. Xu, Y. Feng, A.B. Rogers, M.D. Schrenzel, J.C. Murphy, and J.G. Fox (2002).

**Hepatobiliary inflammation, neoplasia, and argyrophilic bacteria in a ferret colony.** *Veterinary Pathology* 39(2): 173-179. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Hepatobiliary disease was diagnosed in eight of 34 genetically unrelated cohabitating pet ferrets (*Mustela putorius furo*) during a 7-year period. The eight ferrets ranged in age from 5 to 8 years and exhibited chronic cholangiohepatitis coupled with cellular proliferation ranging from hyperplasia to frank neoplasia. Spiral-shaped argyrophilic bacteria were demonstrated in livers of three ferrets, including two with carcinoma. Sequence analysis of a 400-base pair polymerase chain reaction product amplified from DNA derived from fecal bacteria from one ferret demonstrated 98% and 97% similarity to *Helicobacter cholecystus* and *Helicobacter* sp. strain 266-1, respectively. The clustering of severe hepatic disease in these cohabitating

ferroes suggests a possible infectious etiology. The role of *Helicobacter* species and other bacteria in hepatitis and/or neoplasia in ferrets requires further study.

**Descriptors:** ferrets, helicobacter infections, *Helicobacter pylori*, liver diseases, bile duct neoplasms, biliary tract diseases, cholangiocarcinoma, cystadenoma, bacterial DNA, hepatitis, hyperplasia, immunohistochemistry, liver microbiology.

Garner, M.M. (2003). **Focus on diseases of ferrets.** *Exotic DVM* 5(3): 75-80. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, diseases, clinical aspects, glomerulonephritis, lymphatic diseases, mycobacterial diseases, neoplasms, otitis externa, infections.

**Notes:** International conference on exotics (ICE2003), Palm Beach, Florida, USA, 2003.

Garner, M.M., J.T. Raymond, T.D. O'Brien, and R.W. Nordhausen (2004). **Amyloidosis in the black footed ferret (*Mustela nigripes*).** In: *Proceedings: American Association of Zoo Veterinarians, American Association of Wildlife Veterinarians, Wildlife Disease Association: Health and Conservation of Captive and Free-Ranging Wildlife, August 28, 2004-September 3, 2004, San Diego, California, American Association of Zoo Veterinarians*: 185-187 p.

**Descriptors:** *Mustela nigripes*, amyloidosis, occurrence in captivity, black footed ferrets, veterinary medicine.

Good, K.L. (2002). **Ocular disorders of pet ferrets.** *Veterinary Clinics of North America. Exotic Animal Practice* 5(2): 325-339. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Ocular disorders in pet ferrets are becoming more widely recognized as the popularity of these animals as companions increases. Knowledge of the anatomy of ferrets and a thorough examination are critical to accurately diagnosing ocular disease. If recognized early, some conditions can be managed successfully. Veterinarians should continue to report ocular conditions that are encountered in this species to help increase knowledge about these disorders.

**Descriptors:** ferrets, eye anatomy, eye diseases, ferrets anatomy, conjunctivitis, glaucoma diagnosis, ophthalmology.

Govorkova, E.A., J.E. Rehg, S. Krauss, H.L. Yen, Y. Guan, M. Peiris, T.D. Nguyen, T.H. Hanh, P. Puthavathana, H.T. Long, C. Buranathai, W. Lim, R.G. Webster, and E. Hoffman (2006). **Lethality to Ferrets of H5N1 Influenza Viruses Isolated from Humans and Poultry in 2004.** *Journal of Virology* 80(12): 6195. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Descriptors:** ferrets, influenza virus, H5N1, humans, poultry, lethality.

Govorkova, E.A., J.E. Rehg, S. Krauss, H.L. Yen, Y. Guan, M. Peiris, T.D. Nguyen, T.H. Hanh, P. Puthavathana, H.T. Long, C. Buranathai, W. Lim, R.G. Webster, and E. Hoffmann (2005). **Lethality to ferrets of H5N1 influenza viruses isolated from humans and poultry in 2004.** *Journal of Virology* 79(4): 2191-2198. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** The 2004 outbreaks of H5N1 influenza viruses in Vietnam and Thailand were highly lethal to humans and to poultry; therefore, newly emerging avian influenza A viruses pose a continued threat, not only to avian species but also to humans. We studied the pathogenicity of four human and nine avian H5N1/04 influenza viruses in ferrets (an excellent model for influenza studies). All four human isolates were fatal to intranasally inoculated ferrets. The human isolate A/Vietnam/1203/04 (H5N1) was the most pathogenic isolate; the severity of disease was associated with a broad tissue tropism and high virus titers in multiple organs, including the brain. High fever, weight loss, anorexia, extreme lethargy, and diarrhea were observed. Two avian H5N1/04 isolates were as pathogenic as the human viruses, causing lethal systemic infections in ferrets. Seven of nine H5N1/04 viruses isolated from avian species caused mild infections, with virus replication restricted to the upper respiratory tract. All chicken isolates were nonlethal to ferrets. A sequence analysis revealed polybasic amino acids in the hemagglutinin connecting peptides of all H5N1/04 viruses, indicating that multiple molecular differences in other genes are important for a high level of virulence. Interestingly, the human A/Vietnam/1203/04 isolate had a lysine substitution at position 627 of PB2 and had one to eight amino acid changes in all gene products except that of the M1 gene, unlike the A/chicken/Vietnam/C58/04 and

A/quail/Vietnam/36/04 viruses. Our results indicate that viruses that are lethal to mammals are circulating among birds in Asia and suggest that pathogenicity in ferrets, and perhaps humans, reflects a complex combination of different residues rather than a single amino acid difference.

**Descriptors:** ferrets, influenza virus, genetics, mortality, avian pathogenicity, orthomyxoviridae pathogenicity, influenza pathology, influenza A virus, avian classification, poultry diseases.

Govorkova, E.A., R.J. Webby, J. Humberd, J.P. Seiler, and R.G. Webster (2006). **Immunization with reverse-genetics-produced H5N1 influenza vaccine protects ferrets against homologous and heterologous challenge.** *Journal of Infectious Diseases* 194(2): 159-167. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** BACKGROUND: Multiple cases of transmission of avian H5N1 influenza viruses to humans illustrate the urgent need for an efficacious, cross-protective vaccine. METHODS: Ferrets were immunized with inactivated whole-virus vaccine produced by reverse genetics with the hemagglutinin (HA) and neuraminidase genes of A/HK/213/03 virus. Ferrets received a single dose of vaccine (7 or 15 microg of HA) with aluminum hydroxide adjuvant or 2 doses (7 microg of HA each) without adjuvant and were challenged with 10(6) 50% egg infectious doses of A/HK/213/03, A/HK/156/97, or A/Vietnam/1203/04 virus. RESULTS: One or 2 doses of vaccine induced a protective antibody response to the vaccine strain. All immunization regimens completely protected ferrets from challenge with homologous wild-type A/HK/213/03 virus: no clinical signs of infection were observed, virus replication was significantly reduced ( $P < .05$ ) and was restricted to the upper respiratory tract, and spread of virus to the brain was prevented. Importantly, all vaccinated ferrets were protected against lethal challenge with the highly pathogenic strain A/Vietnam/1203/04. The 2-dose schedule induced higher levels of antibodies that were cross-reactive to antigenically distinct H5N1 viruses. CONCLUSIONS: H5N1 vaccines may stimulate an immune response that is more cross-protective than what might be predicted by in vitro assays and, thus, hold potential for being stockpiled as "initial" pandemic vaccines.

**Descriptors:** ferrets, immunology, virology, influenza A virus, H5N1, vaccines, orthomyxoviridae infections.

**Notes:** Comment In: *J Infect Dis.* 2006 Jul 15;194(2):143-5.

Greenacre, C.B. (2003). **Fungal diseases of ferrets.** *Veterinary Clinics of North America. Exotic Animal Practice* 6(2): 435-448, Viii. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Although fungal disease in ferrets is uncommon, a few cases have been documented, demonstrating that it should be on the clinician's rule out list, especially if the patient has a long-term illness that is not responding appropriately to antibiotics, as was the clinical presentation in many of these documented cases.

**Descriptors:** ferrets, mycoses, diagnosis, drug therapy, prognosis, fungal diseases.

Hampson, A.W. (2006). **Ferrets and the challenges of H5N1 vaccine formulation.** *Journal of Infectious Diseases* 194(2): 143-145. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Descriptors:** ferrets, immunology, virology, influenza A virus, H5N1, influenza vaccines, biosynthesis, vaccines, orthomyxoviridae infections.

**Notes:** Comment On: *J Infect Dis.* 2006 Jul 15;194(2):159-67.

Hanley, C. S, P. MacWilliams, S. Giles, and J. Pare (2006). **Diagnosis and successful treatment of *Cryptococcus neoformans* variety grubii in a domestic ferret.** *Canadian Veterinary Journal* 47(10): 1015-1017. ISSN: 0008-5286.

**NAL Call Number:** 41.8 R3224

**Abstract:** A domestic ferret was presented for episodic regurgitation. Cytologic examination and culture of an enlarged submandibular lymph node revealed *Cryptococcus neoformans* variety grubii (serotype A). The ferret was successfully treated with itraconazole. This is the first documented case of *Cryptococcus neoformans* variety grubii in a ferret in the United States.

**Descriptors:** ferret, *Cryptococcus neoformans*, diagnosis, treatment.

Hernandez Divers, S.J. (2005). **Respiratory diseases of rabbits and ferrets.** In: *Small animal and exotics: Proceedings of the North American Veterinary Conference. January 8, 2005-January 12, 2005, Orlando,*

Florida, USA., Eastern States Veterinary Association: Gainesville, USA, Vol. 19, p. 1326-1329.

Online: <http://www.navc.org>

**Descriptors:** ferrets, rabbits, respiratory diseases, diagnosis, treatment, conference.

Iwata, K., Y. Kuwahara, and N. Kuwahara (2002). **Two cases of hyperadrenocorticism in ferrets.** *Journal of the Japan Veterinary Medical Association* 55(3): 163-165. ISSN: 0446-6454.

**Abstract:** Because of high serum levels of 17alpha-hydroxyprogesterone, two ferrets with bilateral symmetrical alopecia of the trunk were tentatively diagnosed as having hyperadrenocorticism. Abdominal computed tomography revealed no obvious adrenal enlargement in either animal. In case 1, treatment with danazol followed by cyproterone acetate produced no fur recovery. Histopathological examinations revealed adrenocortical carcinoma in both animals. In about a month and a half after tumid left adrenal resection, both ferrets' fur had completely recovered. The animals continue in good condition at the present. In case 1, serum 17alpha-hydroxyprogesterone has dropped to the normal range.

**Descriptors:** ferrets, adrenal glands, endocrine diseases, animal glands, endocrine glands, Mustelidae.

**Language of Text:** Japanese.

Jacobs, K.M. (2004). **A ferret model of microgyria: The effect of varying lesion days.** *Epilepsia* 45(Suppl. 7): 44. ISSN: 0013-9580.

**Descriptors:** ferrets as animal models, microgyria, varying lesions, nervous system diseases, epilepsy.

**Notes:** 58th Annual Meeting of the American-Epilepsy-Society, New Orleans, LA, USA; December 03 -07, 2004.

Johnson Delaney, C.A. (2005). **The ferret gastrointestinal tract and *Helicobacter mustelae* infection.** *Veterinary Clinics of North America. Exotic Animal Practice* 8(2): 197-212. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Descriptors:** ferrets, microbiology, gastrointestinal tract, helicobacter infections, *Helicobacter mustelae* pathogenicity, biliary tract, disease models, pancreas, exocrine physiology.

Johnson Delaney, C.A. (2004). **Medical therapies for ferret adrenal disease.** *Seminars in Avian and Exotic Pet Medicine* 13(1): 3-7. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, adrenal gland diseases, adrenalectomy, medical therapies, surgical operations, neoplasia, symptoms.

Johnson Delaney, C.A. (2002). **Update on ferret adrenal research.** *Exotic DVM* 4(3): 61-64. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, adrenal gland diseases, research, update, histopathology, neoplasms, surgical operations, therapy.

**Notes:** 4th Annual international conference on exotics (ICE2002), Key West, Florida, USA, 2002.

Kottwitz, J.J., V. Luis Fuentes, and B. Micheal (2006). **Nonbacterial thrombotic endocarditis in a ferret (*Mustela putorius furo*).** *Journal of Zoo and Wildlife Medicine* 37(2): 197-201. ISSN: 1042-7260.

**NAL Call Number:** SF601.J6

**Descriptors:** ferret, thrombotic endocarditis, nonbacterial, pelvic limb ataxia, cardiac murmur, pathology, clinical aspects, diagnosis, endocarditis, histopathology, postmortem examinations.

Langlois, I. (2005). **Viral diseases of ferrets.** *Veterinary Clinics of North America. Exotic Animal Practice* 8(1): 139-160. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Distemper and rabies vaccination are highly recommended because of the almost invariable fatal outcome of these conditions. Vaccination should constitute an important part of a ferret's preventative medicine program. With the current and anticipated development and licensing of new vaccines, practitioners are invited to gain awareness of the latest vaccine information. Establishment of a practice vaccination protocol with regards to the site of administration of rabies and distemper vaccines is paramount to document any future

abnormal tissue reactions. Influenza is the most common zoonotic disease that is seen in ferrets. Although it generally is benign in most ferrets, veterinarians must take this condition seriously. The characteristic continuous antigenic variation of this virus may lead to more virulent strains; the recent emergence of avian influenza virus outbreaks; and the increased susceptibility of elderly, young, and immunosuppressed individuals.

**Descriptors:** ferrets, viral diseases, distemper, rabies vaccination.

Lennox, A.M. (2005). **Gastrointestinal diseases of the ferret.** *Veterinary Clinics of North America. Exotic Animal Practice* 8(2): 213-225. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Descriptors:** ferrets, gastrointestinal diseases, age factors, diagnosis, differential, foreign bodies, complications, etiology.

Lester, S.J., N.J. Kowalewich, K.H. Bartlett, M.B. Krockenberger, T.M. Fairfax, and R. Malik (2004).

**Clinicopathologic features of an unusual outbreak of cryptococcosis in dogs, cats, ferrets, and a bird: 38 cases (January to July 2003).** *Journal of the American Veterinary Medical Association* 225(11): 1716-1722. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** OBJECTIVE: To determine clinical and pathologic findings associated with an outbreak of cryptococcosis in an unusual geographic location (British Columbia, Canada). DESIGN: Retrospective study. ANIMALS: 1 pink-fronted cockatoo, 2 ferrets, 20 cats, and 15 dogs. PROCEDURE: A presumptive diagnosis of cryptococcosis was made on the basis of serologic, histopathologic, or cytologic findings, and a definitive diagnosis was made on the basis of culture or immunohistochemical staining. RESULTS: No breed or sex predilections were detected in affected dogs or cats. Eleven cats had neurologic signs, 7 had skin lesions, and 5 had respiratory tract signs. None of 17 cats tested serologically for FeLV yielded positive results; 1 of 17 cats yielded positive results for FIV (western blot). Nine of 15 dogs had neurologic signs, 2 had periorbital swellings, and only 3 had respiratory tract signs initially. Microbiologic culture in 15 cases yielded 2 isolates of *Cryptococcus neoformans* var *grubii* (serotype A) and 13 isolates of *C. neoformans* var *gattii* (serotype B); all organisms were susceptible to amphotericin B and ketoconazole. Serologic testing had sensitivity of 92% and specificity of 98%. CONCLUSIONS AND CLINICAL RELEVANCE: Serologic titers were beneficial in identifying infection in animals with nonspecific signs, but routine serum biochemical or hematologic parameters were of little value in diagnosis. Most animals had nonspecific CNS signs and represented a diagnostic challenge. Animals that travel to or live in this region and have nonspecific malaise or unusual neurologic signs should be evaluated for cryptococcosis.

**Descriptors:** ferrets, dogs, cats, birds, epidemiology, diseases, cockatoos, cryptosporidiosis, amphotericin b, antifungal agents, bird diseases, drug therapy, cat diseases, cryptosporidiosis, disease outbreaks, dog diseases, ketoconazole, retrospective studies, treatment outcomes.

Lunn, J.A., P. Martin, S. Zaki, and R. Malik (2005). **Pneumonia due to *Mycobacterium abscessus* in two domestic ferrets (*Mustelo putorius furo*).** *Australian Veterinary Journal* 83(9): 542-546. ISSN: 0005-0423.

**NAL Call Number:** 41.8 Au72

**Abstract:** Two ferrets were diagnosed with pneumonia due to *Mycobacterium abscessus*. Both cases were treated successfully using clarithromycin after positive cultures were obtained via unguided bronchoalveolar lavage. This is the first time *M abscessus* has been isolated in our laboratory and the first report of this organism causing disease in companion animals in Australia. Underlying respiratory tract disease was thought to be an important factor in the development of the infections. Thorough investigation of chronic lower respiratory tract disease in ferrets is recommended as this species appears predisposed to atypical infections.

**Descriptors:** ferrets, anti-bacterial agents, mycobacterium infections, bacterial pneumonia, bronchoalveolar lavage, fluid microbiology, mycobacterium isolation, treatment outcome.

Mader, D.R. and K.L. Rosenthal (2005). **Gastrointestinal diseases in ferrets.** In: *Small animal and exotics: Proceedings of the North American Veterinary Conference., January 8, 2005-January 12, 2005, Orlando, Florida, USA., Eastern States Veterinary Association: Gainesville, USA, Vol. 19, p. 1342-1344.*

**Online:** <http://www.navc.org>

**Descriptors:** ferrets, bacterial diseases, bloat, digestive disorders, digestive tract, oesophageal diseases, parasitoses, regurgitation, ulcers, gastrointestinal.

Malik, R., B. Alderton, D. Finlaison, M.B. Krockenberger, H. Karaoglu, W. Meyer, P. Martin, M.P. France, J. McGill, S.J. Lester, C.R. O'Brien, and D.N. Love (2002). **Cryptococcosis in ferrets: A diverse spectrum of clinical disease.** *Australian Veterinary Journal* 80(12): 749-755. ISSN: 0005-0423.

**NAL Call Number:** 41.8 Au72

**Abstract:** Cryptococcosis was diagnosed in seven ferrets (five from Australia; two from western Canada) displaying a wide range of clinical signs. Two of the ferrets lived together. One (5-years-old) had cryptococcal rhinitis and presented when the infection spread to the nasal bridge. Its sibling developed cryptococcal abscessation of the right retropharyngeal lymph node 12 months later, soon after developing a severe skin condition. DNA fingerprinting and microsatellite analysis demonstrated that the two strains isolated from these siblings were indistinguishable. Two ferrets (2- to 3-years-old) developed generalised cryptococcosis: one had primary lower respiratory tract disease with pneumonia, pleurisy and mediastinal lymph node involvement, while in the other a segment of intestine was the primary focus of infection with subsequent spread to mesenteric lymph nodes, liver and lung. The remaining three ferrets (1.75 to 4-years-old) had localised disease of a distal limb, in one case with spread to the regional lymph node. *Cryptococcus bacillisporus* (formerly *C. neoformans* var *gattii*) accounted for three of the four infections in Australian ferrets where the biotype could be determined. The Australian ferret with intestinal involvement and the two ferrets from Vancouver had *C. neoformans* var *grubii* infections.

**Descriptors:** ferrets, cryptococcosis, *Cryptococcus neoformans*, respiratory tract infections, rhinitis, British Columbia, purification, DNA fingerprinting, microsatellite repeats, New South Wales, polymerase chain reaction, respiratory tract infections.

Marini, R.P., G. Otto, S. Erdman, L. Palley and J.G. Fox (2002). **Biology and diseases of ferrets.** In: J.G. Fox, L.C. Anderson, F.M. Loew and F.W. Quimby (Editors), *Laboratory Animal Medicine*, 2nd edition, Academic Press: London, UK, p. 483-517. ISBN: 0122639510.

**Descriptors:** ferrets, diseases, biology, parasites.

Mayer, J. (2006). **Update on adrenal gland disease in ferrets.** In: *Small animal and exotics: Proceedings of the North American Veterinary Conference. January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1744-1745.

**Online:** <http://www.tnavc.org>

**Descriptors:** ferrets, adrenal gland diseases, update, clinical aspects, diagnosis, treatments.

Miwa, Y., S. Matsunaga, M. Ando, H. Nakayama, K. Uetsuka, H. Nakamura, and H. Ogawa (2005). **Spontaneous Aleutian disease in a ferret infected with the ferret-derived Aleutian-disease virus strain.** *Journal of the Japan Veterinary Medical Association* 58(7): 484-487. ISSN: 0446-6454.

**Descriptors:** ferret, Aleutian disease, spontaneous, clinical aspects.

**Language of Text:** Japanese; Summary in English.

Moorman Roest, J. (2005). **Aleutian disease bij fretten afkomstig uit Nieuw-Zeeland. [Aleutian disease in ferrets from New Zealand].** *Tijdschrift Voor Diergeneeskunde* 130(13): 404-406. ISSN: 0040-7453.

**Descriptors:** ferrets, Aleutian disease, ferrets, viral antibodies, mink, Netherlands, New Zealand.

**Language of Text:** Dutch.

Morrisey, J.K. (2002). **Treatment options for adrenal disease in ferrets.** *Veterinary Cancer Society Newsletter* 26(2): 4-5.

**Descriptors:** ferrets, adrenal diseases, treatment options, drug therapy, surgery.

Nolte, D.M., C.A. Carberry, K.M. Gannon, and F.C. Boren (2002). **Temporary tube cystostomy as a treatment for urinary obstruction secondary to adrenal disease in four ferrets.** *The Journal of the American Animal Hospital Association* 38(6): 527-532. ISSN: 0587-2871.

**NAL Call Number:** SF601.A5

**Descriptors:** ferrets, pets, age, adrenal gland diseases, clinical aspects, urethra, urination disorders, complications, adrenalectomy, surgery, catheterization, catheters, prostate, histopathology, pancreas, omentum, adenoma, adenocarcinoma, adrenal cortex, postoperative care, urination, small animal practice, animal hospitals.

Orcutt, C. (2003). **Urogenital disease in ferrets.** In: *Work/Life Balance, Achieving Equilibrium OVMA Conference Proceedings 2003*, Ontario Veterinary Medical Association: Milton, Canada, p. 36-40.

**Descriptors:** ferrets, urogenital disease, diagnosis, treatment.

**Notes:** Ontario Veterinary Medical Association, Conference Proceedings, January 30-February 1, 2003.

Orcutt, C.J. (2003). **Ferret urogenital diseases.** *Veterinary Clinics of North America. Exotic Animal Practice* 6(1): 113-138. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Improved nutrition and client education have decreased the incidence of certain urinary tract diseases in ferrets. Early neutering programs at commercial breeding farms in the United States have also led to a marked decrease in the incidence of reproductive tract disease, especially estrogen-induced bone marrow suppression. However, the increased incidence of adrenal disease and its secondary effects on reproductive and associated urinary tract tissue presents an ongoing challenge for the clinician working with pet ferrets. Acute and chronic renal failure remain important, though less common, disease entities. It is imperative that the veterinarian working with pet ferrets be aware of the clinical presentation and clinicopathologic abnormalities associated with these syndromes.

**Descriptors:** ferrets, urogenital diseases, diagnosis, surgery, therapy, ultrasonography, nutrition, neutering, reproductive tract disease.

Patterson, M.M., A.B. Rogers, M.D. Schrenzel, R.P. Marini, and J.G. Fox (2003). **Alopecia attributed to neoplastic ovarian tissue in two ferrets.** *Comparative Medicine* 53(2): 213-217. ISSN: 1532-0820.

**NAL Call Number:** SF77 .C65

**Abstract:** Ferrets with adrenal gland dysfunction have alopecia as their most common clinical sign of disease. Two cases of alopecia in neutered female ferrets are reported that were associated instead with neoplastic tissue found at the site of an ovarian pedicle. Androstenedione and 17-hydroxyprogesterone, but not estradiol, concentrations were high in both ferrets. Following surgical resection of the abnormal tissue in one ferret, the high hormone values decreased quickly and hair regrowth ensued. In both cases, histologic examination revealed features consistent with classical sex cord-stromal (gonadostromal) tumors: prominent spindle cells, along with polyhedral epithelial cells and cells with vacuolated cytoplasm. Although similar cell types have been described in the adrenal glands of ferrets with adrenal-associated endocrinopathy, an ovarian origin for the current neoplasms is considered likely on the basis of their anatomic location; accessory adrenal tissue has only been described close to an adrenal gland or in the cranial perirenal fat of ferrets. Immunohistochemical analysis, using an antibody against Mullerian-inhibiting substance, failed to prove definitively the source of the steroidogenic cells.

**Descriptors:** ferrets, alopecia, adrenal gland diseases, ovarian cancer, estradiol, progesterone, androstenedione, immunohistochemistry, excision of the ovaries.

Peltola, V.T., K.L. Boyd, J.L. McAuley, J.E. Rehg, and J.A. McCullers (2006). **Bacterial sinusitis and otitis media following influenza virus infection in ferrets.** *Infection and Immunity* 74(5): 2562-2567. ISSN: 1098-5522.

**NAL Call Number:** QR1.I57

**Abstract:** *Streptococcus pneumoniae* is the leading cause of otitis media, sinusitis, and pneumonia. Many of these infections result from antecedent influenza virus infections. In this study we sought to determine whether the frequency and character of secondary pneumococcal infections differed depending on the strain of influenza virus that preceded bacterial challenge. In young ferrets infected with influenza virus and then challenged with pneumococcus, influenza viruses of any subtype increased bacterial colonization of the nasopharynx. Nine out of 10 ferrets infected with H3N2 subtype influenza A viruses developed either sinusitis or otitis media, while only 1 out of 11 ferrets infected with either an H1N1 influenza A virus or an influenza B virus did so. These data may partially explain why bacterial complication rates are higher during seasons when H3N2 viruses predominate. This animal model will be useful for further study of the mechanisms that underlie viral-bacterial

synergism.

**Descriptors:** ferrets, bacterial infection, virus infection, sinusitis, pneumonia, viral-bacterial synergism.

Pennick, K.E., M.A. Stevenson, K.S. Latimer, B.W. Ritchie, and C.R. Gregory (2005). **Persistent viral shedding during asymptomatic Aleutian mink disease parvoviral infection in a ferret.** *Journal of Veterinary Diagnostic Investigation* 17(6): 594-597. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** A 2-year-old domestic ferret that appeared clinically healthy was repeatedly seropositive for Aleutian mink disease parvovirus (ADV) over a 2-year observation period. Antibody titers, determined by counter-immunoelectrophoresis, ranged from 1024 to 4096. Viral DNA also was identified in serum, urine, feces, and blood cell fractions by polymerase chain reaction analysis. Ultimately, DNA in situ hybridization revealed ADV DNA in histologic sections of various tissues and organs. These data indicate that this asymptomatic ferret was persistently infected with ADV.

**Descriptors:** ferrets, Aleutian mink disease, virology, carrier state, virus shedding, antibodies, blood, physiopathology, DNA, physiology, kidney, liver, lung, spleen, urine.

Prohaczik, A., K. Fodor, M. Kulcsar, and G. Huszenicza (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei. Irodalmi attekintes. 1. A faj bemutatasa, taplalasa es ivari mukodesenek elettana. [Reproduction, genital malfunctions and endocrine disorders of domestic ferret (*Mustela putorius furo*). Literature review. 1. Biology, zootaxonomy, nutrition and physiology of reproduction].** *Magyar Allatorvosok Lapja* 126(6): 353-363. ISSN: 0025-004X.

**Descriptors:** ferret, biology, endocrine diseases, female genital diseases, nutrition, reproduction, reviews, taxonomy.

**Language of Text:** Hungarian; Summary in English.

Prohaczik, A., M. Kulcsar, and G. Huszenicza (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei. Irodalmi attekintes. 2. Ivarszervi mukodeszavarok, megbetegedések. [Reproduction, genital malfunctions and endocrine disorders of domestic ferret (*Mustela putorius furo*). Literature review. 2. Pathology of reproduction].** *Magyar Allatorvosok Lapja* 126(6): 364-369. ISSN: 0025-004X.

**Descriptors:** ferret, genital diseases, endocrine disorders, genital malfunctions, pregnancy, pyometra, reproductive disorders, reviews, pathology.

**Language of Text:** Hungarian; Summary in English.

Ramer, J.C., K.G. Benson, J.K. Morrissey, R.T. O'brien, and J. Paul Murphy (2006). **Effects of melatonin administration on the clinical course of adrenocortical disease in domestic ferrets.** *Journal of the American Veterinary Medical Association* 229(11): 1743-1748. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** Objective-To evaluate the effect of oral administration of melatonin on clinical signs, tumor size, and serum steroid hormone concentrations in ferrets with adrenocortical disease. Design-Noncontrolled clinical trial. Animals-10 adult ferrets with clinical signs of adrenocortical disease (confirmed via serum steroid hormone concentration assessments). Procedures-Melatonin (0.5 mg) was administered orally to ferrets once daily for 1 year. At 4-month intervals, a complete physical examination; abdominal ultrasonographic examination (including adrenal gland measurement); CBC; serum biochemical analyses; and assessment of serum estradiol, androstenedione, and 17alpha-hydroxyprogesterone concentrations were performed. Serum prolactin and dehydroepiandrosterone sulfate concentrations were evaluated at the first, second, and last examinations, and serum cortisol concentration was evaluated at the first and last examinations. Results-Daily oral administration of melatonin greatly affected clinical signs of adrenocortical disease in ferrets; changes included hair regrowth, decreased pruritus, increased activity level and appetite, and decreased vulva or prostate size. Mean width of the abnormally large adrenal glands was significantly increased after the 12-month treatment period. Recurrence of clinical signs was detected in 6 ferrets at the 8-month evaluation. Compared with pretreatment values, serum 17alpha-hydroxyprogesterone and prolactin concentrations were significantly increased and decreased after 12 months, respectively. Conclusions and Clinical Relevance-Results suggest that melatonin is a useful, easily administered, palliative treatment to decrease clinical signs associated with adrenocortical disease in ferrets, and

positive effects of daily treatment were evident for at least an 8-month period. Oral administration of melatonin did not decrease adrenal gland tumor growth in treated ferrets.

**Descriptors:** domestic ferrets, adrenocortical disease, melatonin, clinical signs.

Rosenthal, K.L. (2006). **Feeding the hypoglycemic ferret.** In: *Small animal and exotics Proceedings of the North American Veterinary Conference. January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1766.

**Online:** <http://www.tnavc.org>

**Descriptors:** feeding, ferret feeding, hypoglycemia.

Saunders, G.K. and B.V. Thomsen (2006). **Lymphoma and *Mycobacterium avium* infection in a ferret (*Mustela putorius furo*).** *Journal of Veterinary Diagnostic Investigation* 18(5): 513-515. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** A 6-year-old, neutered male ferret presented with weight loss. Radiography revealed an enlarged liver and other abdominal masses. The ferret was euthanized, and at necropsy, the stomach wall was thickened, mesenteric lymph nodes were enlarged, and the liver contained multifocal tan nodules. Histopathology confirmed lymphoma and granulomatous inflammation in all affected organs. Acid-fast bacilli were present in the lesions and were confirmed to be *Mycobacterium avium* by PCR.

**Descriptors:** ferrets, lymphoma, *Mycobacterium avium*, tuberculosis, fatal outcome, histocytochemistry, lymphoma.

Schoemaker, N.J. and P.G. Fisher (2004). **Hyperadrenocorticism in ferrets: An interpretive summary.** *Exotic DVM* 6(1): 43-45. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, hyperadrenocorticism, adrenal glands, clinical aspects, gonadectomy, hormone secretion, LH, summary.

Schoemaker, N.J., M.H. Hage van der, G. Flik, J.T. Lumeij, and A. Rijnberk (2004). **Morphology of the pituitary gland in ferrets (*Mustela putorius furo*) with hyperadrenocorticism.** *Journal of Comparative Pathology* 130(4): 255-265. ISSN: 0021-9975.

**NAL Call Number:** 41.8 J82

**Descriptors:** ferrets, diseases, adrenal glands, histopathology, neoplasms, physiopathology, pituitary, morphology.

Schoemaker, N.J., J.T. Lumeij, and A. Rijnberk (2005). **Current and future alternatives to surgical neutering in ferrets to prevent hyperadrenocorticism.** *Veterinary Medicine* 100(7): 484-485, 488, 490, 492, 495-496. ISSN: 8750-7943.

**NAL Call Number:** 41.8 M69

**Descriptors:** ferrets, hyperadrenocorticism, surgical neutering, alternatives, diseases.

Schoemaker, N.J., K.J. Teerds, J.A. Mol, J.T. Lumeij, J.H. Thijssen, and A. Rijnberk (2002). **The role of luteinizing hormone in the pathogenesis of hyperadrenocorticism in neutered ferrets.** *Molecular and Cellular Endocrinology* 197(1-2): 117-125. ISSN: 0303-7207.

**Abstract:** Four studies were performed to test the hypothesis that gonadotrophic hormones, and particularly luteinizing hormone (LH) play a role in the pathogenesis of ferrets: (I) adrenal glands of ferrets with hyperadrenocorticism were studied immunohistochemically to detect LH-receptors (LH-R); (II) gonadotrophin-releasing hormone (GnRH) stimulation tests were performed in 10 neutered ferrets, with measurement of androstenedione, 17alpha-hydroxyprogesterone and cortisol as endpoints; (III) GnRH stimulation tests were performed in 15 ferrets of which 8 had hyperadrenocorticism, via puncture of the vena cava under anesthesia; and (IV) urinary corticoid/creatinine (C/C) ratios were measured at 2-week intervals for 1 year in the same ferrets as used in study II. Clear cells in hyperplastic or neoplastic adrenal glands of hyperadrenocorticoid ferrets stained positive with the LH-R antibody. Plasma androstenedione and 17alpha-hydroxyprogesterone concentrations increased after stimulation with GnRH in 7 out of 8 hyperadrenocorticoid ferrets but in only 1 out of 7 healthy ferrets. Hyperadrenocorticoid ferrets had elevated urinary C/C ratios during the breeding

season. The observations support the hypothesis that gonadotrophic hormones play a role in the pathogenesis of hyperadrenocorticism in ferrets. This condition may be defined as a disease resulting from the expression of LH-R on sex steroid-producing adrenocortical cells.

**Descriptors:** adrenocortical hyperfunction, ferrets, luteinizing hormone, orchietomy, 17 alpha hydroxyprogesterone, adenoma, adrenal cortex, adrenocortical hyperfunction, androstenedione, gonadorelin, hydrocortisone, LH receptors, urine.

Schoemaker, N.J., K.J. Teerds, J.A. Mol, J.T. Lumeij, J.H.H. Thijssen, and A. Rijnberk (2004). **The role of luteinizing hormone in the pathogenesis of hyperadrenocorticism in neutered ferrets.** *European Journal of Companion Animal Practice* 14(1): 69-76. ISSN: 1018-2357.

**Descriptors:** ferrets, hyperadrenocorticism, pathogenesis, lutenizing hormone, neutered ferrets, adrenal glands, hydrocortisone, LH receptors.

Schoemaker, N.J., M.H. van der Hage, G. Flik, J.T. Lumeij, and A. Rijnberk (2004). **Morphology of the pituitary gland in ferrets (*Mustela putorius furo*) with hyperadrenocorticism.** *Journal of Comparative Pathology* 130(4): 255-265. ISSN: 0021-9975.

**NAL Call Number:** 41.8 J82

**Abstract:** Pituitary tumours are the cause of hyperadrenocorticism in a variety of species, but the role of the pituitary gland in hyperadrenocorticism in ferrets is not known. In this species, the disease is mediated by the action of excess gonadotrophins on the adrenal cortex and is characterized by an excessive secretion of sex steroids. In this study, the pituitary gland of four healthy control ferrets, intact or neutered, and 10 neutered ferrets with hyperadrenocorticism was examined histologically following immunohistochemical labelling for adrenocorticotrophic hormone, alpha-melanocyte-stimulating hormone, growth hormone, thyroid-stimulating hormone, luteinizing hormone, follicle-stimulating hormone, and prolactin. Immunohistochemistry revealed that somatotrophs, thyrotrophs and lactotrophs were the most abundant cell types of the pars distalis of the pituitary gland in the healthy ferrets. The distribution of corticotrophs was similar to that in the dog and man. In ferrets, as in dogs, the melanotrophic cell was almost the only cell type of the pars intermedia. Gonadotrophs were found in the pars distalis of neutered, but not intact ferrets. All the ferrets with hyperadrenocorticism had unilateral or bilateral alterations of the adrenal gland. In addition, in the pituitary gland of two of these ferrets a tumour was detected. These tumours were not immunolabelled by antibodies against any of the pituitary hormones, and had characteristics of the clinically non-functional gonadotroph tumours seen in man. In some of the other ferrets low pituitary immunoreactivity for gonadotrophic hormones was detected, which may have been due to the feedback of autonomous steroid secretion by the neoplastic transformation of the adrenal cortex. It is concluded that initially high concentrations of gonadotrophins resulting from castration may initiate hyperactivity of the adrenal cortex. The low incidence of pituitary tumours and the low density of gonadotrophin-positive cells in non-affected pituitary tissue in this study suggest that persistent hyperadrenocorticism is not dependent on persistent gonadotrophic stimulation.

**Descriptors:** ferrets, adrenocortical hyperfunction, pituitary gland, adenoma, adrenal glands, castration, pituitary neoplasms.

Schoemaker, N.J., J. Wolfswinkel, J.A. Mol, G. Voorhout, M.J.L. Kik, J.T. Lumeij, and A. Rijnberk (2004). **Urinary glucocorticoid excretion in the diagnosis of hyperadrenocorticism in ferrets.** *Domestic Animal Endocrinology* 27(1): 13-24. ISSN: 0739-7240.

**NAL Call Number:** QL868.D6

**Abstract:** Hyperadrenocorticism in ferrets is usually associated with unaltered plasma concentrations of cortisol and adrenocorticotrophic hormone (ACTH), although the urinary corticoid/creatinine ratio (UCCR) is commonly elevated. In this study the urinary glucocorticoid excretion was investigated in healthy ferrets and in ferrets with hyperadrenocorticism under different circumstances. In healthy ferrets and in one ferret with hyperadrenocorticism, approximately 10% of plasma cortisol and its metabolites was excreted in the urine. High-performance liquid chromatography (HPLC) revealed one third of the urinary corticoids to be unconjugated cortisol; the other peaks mainly represented cortisol conjugates and metabolites. In 21 healthy sexually intact ferrets, the UCCR started to increase by the end of March and declined to initial values halfway the breeding season (June). In healthy neutered ferrets there was no significant seasonal influence on the UCCR. In two neutered ferrets with hyperadrenocorticism the UCCR was increased, primarily during the breeding

season. In 27 of 31 privately owned ferrets with hyperadrenocorticism, the UCCR was higher than the upper limit of the reference range ( $2.1 \times 10^{-6}$ ). In 12 of 14 healthy neutered ferrets dexamethasone administration decreased the UCCR by more than 50%, whereas in only 1 of the 28 hyperadrenocorticoid ferrets did the UCCR decrease by more than 50%. We conclude that the UCCR in ferrets primarily reflects cortisol excretion. In healthy sexually intact ferrets and in ferrets with hyperadrenocorticism the UCCR increases during the breeding season. The increased UCCR in hyperadrenocorticoid ferrets is resistant to suppression by dexamethasone, indicating ACTH-independent cortisol production.

**Descriptors:** ferrets, hyperadrenocorticism, disease diagnosis, urine, glucocorticoids, cortisol, excretion, metabolites, creatinine, breeding season, seasonal variation, dexamethasone, urinary corticoid-creatinine ratio (UCCR).

Ter Meulen, J., A.B.H. Bakker, E.N. Van Den Brink, G.J. Weverling, B.E.E. Martina, B.L. Haagmans, T. Kuiken, J. De Kruif, W. Preiser, W. Spaan, H.R. Gelderblom, J. Goudsmit, and A.D.M.E. Osterhaus (2004). **Human monoclonal antibody as prophylaxis for sars coronavirus infection in ferrets.** *Lancet* 363(9427): 2139-2141. ISSN: 0099-5355.

**Descriptors:** ferrets, SARS infection, coronavirus infection, human monoclonal antibody, prophylaxis, severe acute respiratory syndrome, animal model.

Triantafyllou, A., D. Fletcher, and J. Scott (2006). **Histological and histochemical observations on salivary microliths in ferret.** *Archives of Oral Biology* 51(3): 198-205. ISSN: 0003-9969.

**Abstract:** The fortuitous observation of salivary microliths in ferret was pursued in the present investigation. Major salivary glands obtained post-mortem from mature ferrets of either sex were examined with the use of histology and light microscopical histochemistry for calcium, protein, amino acids, mucosubstances and hydrolytic enzymes. Microliths were detected in most parotids, but were absent from submandibular and sublingual glands. The microliths were usually seen in lumens, and occasionally in parenchyma and interstices. They were variably stained for calcium, tryptophan, and neutral and acidic mucosubstances, similarly to acinar or ductal secretory granules. Unlike secretory granules, microliths showed autofluorescence, high levels of tyrosine and a low concentration of -SS- groups. Acid phosphatase and beta-glucuronidase reaction surrounded non-luminal microliths. The present data establish ferret as a new model for the investigation of salivary microliths and do not support the notion of microliths being almost absent from the parotid. Probably there is secretory inactivity in ferret parotid and this fosters the formation and accumulation of microliths containing calcium and disintegrated secretory material.

**Descriptors:** ferrets, salivary gland, calculi, pathology, salivary gland diseases, pathology, parotid diseases, metabolism, pathology, parotid gland, calculi chemistry, submandibular gland diseases, metabolism, submandibular gland diseases, pathology.

von Messling, V., C. Springfield, P. Devaux, and R. Cattaneo (2003). **A ferret model of canine distemper virus virulence and immunosuppression.** *Journal of Virology* 77(23): 12579-12591. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** Canine distemper virus (CDV) infects many carnivores, including ferrets and dogs, and is the member of the Morbillivirus genus most easily amenable to experimentation in a homologous small-animal system. To gain insights into the determinants of CDV pathogenesis, we isolated a strain highly virulent for ferrets by repeated passaging in these animals. Sequence comparison of the genome of this strain with that of its highly attenuated precursor revealed 19 mutations distributed almost evenly in the six genes. We then recovered a virus from a cDNA copy of the virulent CDV strain's consensus sequence by using a modified reverse genetics system based on B cells. We infected ferrets with this virus and showed that it fully retained virulence as measured by the timing of rash appearance, disease onset, and death. Body temperature, leukocyte number, lymphocyte proliferation activity, and cell-associated viremia also had similar kinetics. We then addressed the question of the relative importance of the envelope and other viral constituents for virulence. Viruses in which the envelope genes (matrix, fusion, and hemagglutinin) of the virulent strain were combined with the other genes of the attenuated strain caused severe rash and fever even if the disease onset was delayed. Viruses in which the nucleocapsid, polymerase, and phosphoprotein genes (coding also for the V and C proteins) of the virulent strain were combined with the envelope genes of the attenuated strain caused milder signs of disease. Thus, virulence-inducing mutations have accumulated throughout the genome.

**Descriptors:** ferrets, animal disease models, distemper virus, canine pathogenicity, immunosuppression, b lymphocytes immunology, DNA, canine genetics, vero cells, virulence genetics.

Wagner, R.A., C.A. Piche, W. Jochle, and J.W. Oliver (2005). **Clinical and endocrine responses to treatment with deslorelin acetate implants in ferrets with adrenocortical disease.** *American Journal of Veterinary Research* 66(5): 910-914. ISSN: 0002-9645.

**NAL Call Number:** 41.8 Am3A

**Abstract:** OBJECTIVE: To evaluate the clinical and endocrine responses of ferrets with adrenocortical disease (ACD) to treatment with a slow-release implant of deslorelin acetate. ANIMALS: 15 ferrets with ACD. PROCEDURE: Ferrets were treated SC with a single slow-release, 3-mg implant of deslorelin acetate. Plasma estradiol, androstenedione, and 17-hydroxyprogesterone concentrations were measured before and after treatment and at relapse of clinical signs; at that time, the adrenal glands were grossly or ultrasonographically measured and affected glands that were surgically removed were examined histologically. RESULTS: Compared with findings before deslorelin treatment, vulvar swelling, pruritus, sexual behaviors, and aggression were significantly decreased or eliminated within 14 days of implantation; hair regrowth was evident 4 to 6 weeks after treatment. Within 1 month of treatment, plasma hormone concentrations significantly decreased and remained decreased until clinical relapse. Mean time to recurrence of clinical signs was 13.7 +/- 3.5 months (range, 8.5 to 20.5 months). In 5 ferrets, large palpable tumors developed within 2 months of clinical relapse; 3 of these ferrets were euthanatized because of adrenal gland tumor metastasis to the liver or tumor necrosis. CONCLUSIONS AND CLINICAL RELEVANCE: In ferrets with ACD, a slow-release deslorelin implant appears promising as a treatment to temporarily eliminate clinical signs and decrease plasma steroid hormone concentrations. Deslorelin may not decrease adrenal tumor growth in some treated ferrets. Deslorelin implants may be useful in the long-term management of hormone-induced sequelae in ferrets with ACD and in treatment of animals that are considered at surgical or anesthetic risk.

**Descriptors:** ferrets, adrenal cortex diseases, triptorelin administration, aging, drug implants, gonadal steroid hormones.

White, S.D. (2006). **Rabbit, rodent and ferret dermatology.** In: *Ahead of the curve: OVMA Conference Proceedings, January 26, 2006-January 28, 2006*, Ontario Veterinary Medical Association: Milton, Canada, p. 102-115.

**Online:** <http://www.ovma.org>

**Descriptors:** ferrets, rabbits, rodents, dermatology, etiology, alopecia, clinical aspects, diagnosis, drug therapy, ectoparasites, pruritus, skin diseases.

Wills, T.B., A.A. Bohn, N.P. Finch, S.P. Harris, and P. Caplazi (2005). **Thyroid follicular adenocarcinoma in a ferret.** *Veterinary Clinical Pathology* 34(4): 405-408. ISSN: 0275-6382.

**NAL Call Number:** SF601.A54

**Abstract:** A 5-year-old male castrated ferret was presented to the Washington State University College of Veterinary Medicine for evaluation of progressive hair loss and a large, rapidly growing ventral neck mass. The patient had been diagnosed previously with an insulinoma, which was managed medically. Fine-needle aspirates of the neck mass were performed. The cytologic results were most consistent with epithelial neoplasia, likely a carcinoma; thyroid origin was considered likely based on tumor location and cell morphology. The tumor grew rapidly, and the owners elected euthanasia 1 week after examination. At necropsy, a circumscribed, ovoid mass disrupted the right cervical musculature next to the right lobe of the thyroid gland. Histopathologic evaluation revealed an infiltrative mass consisting of cuboidal cells arranged in solid sheets and irregular follicles enclosing colloid. The cells were large, with prominent nucleoli, and had a high mitotic rate. The histopathologic diagnosis was consistent with thyroid follicular adenocarcinoma. Immunochemical findings confirmed thyroglobulin production by neoplastic cells, but to a lesser extent than in normal ferret thyroid tissue. To our knowledge, this is the first case of thyroid follicular adenocarcinoma to be reported in a ferret, with only 1 other case of thyroid carcinoma, a C-cell carcinoma, described previously.

**Descriptors:** ferrets, follicular adenocarcinoma, thyroid neoplasms, immunohistochemistry, thyroid gland, neoplasms, case study.

Woods, J.B., C.K. Schmitt, S.C. Darnell, K.C. Meysick, and A. O'Brien (2002). **Ferrets as a model system for renal disease secondary to intestinal infection with *Escherichia coli* O157:H7 and other Shiga toxin-producing**

*E. coli*. *Journal of Infectious Diseases* 185(4): 550-554. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** Ferrets were evaluated as a possible small animal model for the development of colitis and/or signs of the hemolytic uremic syndrome after oral infection with *Escherichia coli* O157:H7 or other Shiga toxin--producing *E. coli* (STEC). Ferrets treated with streptomycin (Stm) had higher counts of *E. coli* O157:H7 strain 86-24 Stm-resistant (Stm(r)) or O91:H21 strain B2F1 Stm(r) in their stools than non--Stm-treated animals. None of the animals displayed evidence of colitis, but Stm-treated animals fed strain 86-24 Stm(r) exhibited weight loss significantly greater than that exhibited by ferrets fed an isogenic mutant negative for the adhesin intimin. Moreover, 11 (23%) of the 47 Stm-treated ferrets inoculated with 86-24 Stm(r) or B2F1 Stm(r) developed hematuria and/or histological damage to glomeruli or thrombocytopenia, compared with 0 of 14 uninfected control animals receiving Stm in water. Thus, the ferret may serve as a model for renal disease secondary to intestinal infection with STEC.

**Descriptors:** ferrets, animal disease models, *Escherichia coli* infections, *Escherichia coli* o157 pathogenicity, *Escherichia coli* proteins, intestinal diseases, kidney diseases, shiga toxin, intestinal diseases, streptomycin .

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## Information Resources on the Care and Welfare of Ferrets

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### Emesis

Endo, T., M. Minami, M. Hirafuji, N. Hamaue, and S.H. Parvez (2004). **The ferret: A cytotoxic drug-induced emesis model.** *Biogenic Amines* 18(3-6): 419-434. ISSN: 0168-8561.

**Descriptors:** ferret, animal model, emesis, Mustela, cytotoxic drugs, vagus nerve, emetic stimuli, Cisplatin induced, vagotomy.

Kan, K.K., R.L. Jones, M.P. Ngan, and J.A. Rudd (2002). **Actions of prostanoids to induce emesis and defecation in the ferret.** *European Journal of Pharmacology* 453(2-3): 299-308. ISSN: 0014-2999.

**Abstract:** Several prostanoids were investigated for their ability to induce emesis and/or defecation and tenesmus in the ferret. The rank order of emetic potency (dose producing four episodes, D4) was: sulprostone (5 microg/kg)>11 alpha,9alpha-epoxymethano-15S-hydroxyprosta-5Z,13E-dienoic acid (U46619; 8 microg/kg)>misoprostol (27 microg/kg)>17-phenyl-omega-trinor prostaglandin E2 (53 microg/kg)>prostaglandin E2 (94 microg/kg)>5-(6-carboxyhexyl)-1-(3-cyclohexyl-3-hydroxypropyl) hydantoin (BW245C; 148 microg/kg)>>prostaglandin F(2alpha) (13,500 microg/kg). Emesis was also induced by iloprost (D4 not determined) and prostaglandin E2 methyl ester (D4=350 microg/kg). Cicaprost and fluprostenol were virtually inactive; they also failed to modify copper sulphate (100 mg/kg, intragastric)-induced emesis (P>0.05), although cicaprost potentiated apomorphine (0.25 mg/kg, s.c.)-induced emesis (P<0.05). U46619-induced emesis was antagonised by vapiprost (P<0.05). The rank order of potency to produce defecation and tenesmus (dose producing three episodes) was: sulprostone (12 microg/kg)>misoprostol (15 microg/kg)>17-phenyl-omega-trinor prostaglandin E2 (94 microg/kg)>prostaglandin E2 (113 microg/kg)>fluprostenol (158 microg/kg).z.Gt;prostaglandin F(2alpha) (1759 microg/kg); prostaglandin E2 methyl ester also induced defecation (196 microg/kg). Data are discussed in relation to mechanisms involved in emesis and defecation.

**Descriptors:** ferrets, defecation, prostaglandins, chemically induced vomiting, dose response relationship.

Kan, K.K., J.A. Rudd, and M.K. Wai (2006). **Differential action of anti-emetic drugs on defecation and emesis induced by prostaglandin E2 in the ferret.** *European Journal of Pharmacology* 544(1-3): 153-159. ISSN: 0014-2999.

**Abstract:** In the present studies we investigated the mechanism of action of prostaglandin E2 (1 mg/kg, i.p.) to induce emesis and defecation and/or tenesmus in the ferret. The emesis was antagonized significantly (P<0.05) by ondansetron (0.3 and 1 mg/kg, i.p.) and (+)-(2S,3S)-3-(2-methoxybenzylamino)-2-phenylpiperidine hydrochloride (CP-99,994; 10 mg/kg, i.p.), but neither compound reduced defecations and/or tenesmus, with ondansetron (0.3 mg/kg) actually producing a slight increase (P<0.05). Droperidol (1 and 3 mg/kg), metoclopramide (0.3 and 3 mg/kg), domperidone (0.3 and 3 mg/kg), promethazine (0.3 and 3 mg/kg) and scopolamine (0.3 and 3 mg/kg) failed to reduce prostaglandin E2 induced emesis. However, droperidol (1 and 3 mg/kg) and scopolamine (0.3 and 3 mg/kg) reduced significantly the defecatory and/or tenesmus response (P<0.05). Bilateral abdominal vagotomy was ineffective to reduce emesis and defecations and/or tenesmus. The data suggests that 5-HT3 receptor and NK1 tachykinin receptor antagonists could be useful in the clinic to prevent emesis but not defecations induced by prostaglandin E2.

**Descriptors:** ferret, anti-emetic drugs, prostaglandin E2, emesis, defecations, tenesmus.

King, A.G. and G.J. Sanger (2005). **Effect of a selective and potent central nervous system penetrant, neurokinin-3 receptor antagonist (SB-222200), on cisplatin-induced emesis in the ferret.** *Neuroscience Letters* 376(1): 5-8. ISSN: 0304-3940.

**Abstract:** The anti-emetic activity of selective NK-1 receptor antagonism is well established. However, little is known of the possibility that other NK receptors might also be involved in the emetic reflex. Given the reported location of NK-3 receptors within the rat brainstem vagal motor and sensory nuclei, we investigated the ability of SB-222200, a brain-penetrant NK-3 receptor antagonist, to interfere with emesis evoked in ferrets by the emetogenic cytotoxic agent cisplatin. In contrast to control anti-emetic experiments using the 5-HT<sub>3</sub> receptor antagonist ondansetron, SB-222200 was found to have no effects on cisplatin-induced vomiting or on the associated reductions in feeding and drinking behaviors at any dose tested. We suggest that if NK-3 receptors are involved in the mechanisms of cisplatin-induced nausea and vomiting, they play only a minor role, relative to the major anti-emetic activity exhibited by 5-HT<sub>3</sub> or NK-1 receptor antagonism.

**Descriptors:** ferrets, therapeutic use of antiemetics, quinolines, vomiting, drug therapy, behavior, carrier proteins, cisplatin, dose response relationship, drug interactions.

Lao, L., G. Zhang, R.H. Wong, A.K. Carter, R.L. Wynn, and B.M. Berman (2003). **The effect of electroacupuncture as an adjunct on cyclophosphamide-induced emesis in ferrets.** *Pharmacology, Biochemistry, and Behavior* 74(3): 691-699. ISSN: 0091-3057.

**Abstract:** The effect of electroacupuncture (EA) on cyclophosphamide-induced emesis in ferrets was studied at acupuncture point Neiguan (P6) with various electrical stimulation parameters (5-100 Hz, 1.5-3 V, 5-20 min, n=6/group). The combination therapy of EA (100 Hz, 1.5 V and 10 min) with the lower doses of ondansetron (0.04 mg/kg), droperidol (0.25 mg/kg) and metoclopramide (2.24 mg/kg) significantly reduced the total number of emetic episodes by 52%, 36% and 73%, respectively, as well as the number of emetic episodes in the first phase as compared to the sham acupuncture control (P<.01). These EA/drug combinations also showed a significant effect in preventing emesis as compared to either EA or drug alone (P<.05). The present study suggests that acupuncture may be useful as an adjunctive therapy in the treatment of chemotherapy-induced emesis.

**Descriptors:** ferrets, induced emesis, electroacupuncture, vomiting, antiemetics, combined modality therapy methods.

Lau, A.H., K.K. Kan, H.W. Lai, M.P. Ngan, J.A. Rudd, M.K. Wai, and D.T. Yew (2005). **Action of ondansetron and CP-99,994 to modify behavior and antagonize cisplatin-induced emesis in the ferret.** *European Journal of Pharmacology* 506(3): 241-247. ISSN: 0014-2999.

**Abstract:** The action of ondansetron (1 mg/kg, i.p.) and (+)-(2S,3S)-3-(2-methoxybenzylamino)-2-phenylpiperidine (CP-99,994; 10 mg/kg, i.p.) on spontaneous behavior and the emesis induced by cisplatin (10 mg/kg, i.p.) was studied in the ferret. Ondansetron was inactive to modify behavior, but CP-99,994 reduced spontaneous locomotor activity and lip licking by 48% (P<0.01) and 79% (P<0.01), respectively; CP-99,994 also abolished spontaneous burrowing activity (P<0.05). Treatment of animals with cisplatin induced an emetic response that was abolished by both ondansetron and CP-99,994 (P<0.01). However, cisplatin did not significantly modify other behavioral measures although animals that received CP-99,994, cisplatin, or CP-99,994 in combination with cisplatin exhibited more episodes of defecation than animals that received ondansetron (P<0.05). The action of CP-99,994 to modify behavior in this species is discussed in relation to animal models of nausea.

**Descriptors:** ferrets, behavior, cisplatin antagonists, ondansetron, piperidines, vomiting, therapeutic use of antiemetics, animal physiology.

Lau, A.H., M.P. Ngan, J.A. Rudd, and D.T. Yew (2005). **Differential action of domperidone to modify emesis and behaviour induced by apomorphine in the ferret.** *European Journal of Pharmacology* 516(3): 247-252. ISSN: 0014-2999.

**Abstract:** The action of domperidone (1 mg/kg, i.p.) on spontaneous behaviour and the emesis and behavioural change induced by apomorphine (0.25 mg/kg, s.c.) were studied in the ferret. Domperidone was inactive to modify spontaneous behaviour but apomorphine-induced emesis and increased locomotor activity (distance travelled and velocity of movement; P<0.05); the emesis, but not the modification of locomotor activity was

antagonized significantly ( $P < 0.01$ ) by domperidone. However, apomorphine did not modify significantly other behavioural measures (i.e. lip licking, rearing, burrowing, backward walking, curling-up activity, or defecatory frequency;  $P > 0.05$ ). The action of apomorphine to modify behaviour and its interaction with domperidone in this species is discussed in relation to animal models of nausea.

**Descriptors:** ferrets, antiemetics, apomorphine, behavior, domperidone pharmacology, vomiting, antiparkinson agents, motor activity, rats, chemically induced vomiting.

Lau, A.H.Y., K.K.W. Kan, H.W. Lai, M.P. Ngan, J.A. Rudd, and D.T.W. Yew (2003). **Action of emetic drugs in the ferret and *Suncus murinus* (house musk shrew): New models of nausea?** *Journal of Veterinary Pharmacology and Therapeutics* 26(Supplement 1): 157. ISSN: 0140-7783.

**NAL Call Number:** SF915.J63

**Descriptors:** emesis, ferret, musk shrew, animal models, emetic drugs, action, nausea, meeting abstract.

**Notes:** Proceedings of the 9th International Congress of the European Association for Veterinary Pharmacology and Toxicology, Lisbon, Portugal; July 13-18, 2003.

Lightbown, I.D., W.D. Miner, and J.D. Gale (2002). **The anti-emetic activity of s(-)-eticlopride against morphine- and ipecacuanha-induced emesis in the conscious ferret.** *British Journal of Pharmacology* 136(Proceedings Supplement): 61P. ISSN: 0007-1188.

**Descriptors:** ferret, anti emetic activity, s(-)-eticlopride, morphine, induced emesis, ipecacuanha, meeting abstract.

**Notes:** Proceedings of the British Journal of Pharmacology, Hatfield, Hertfordshire, UK; April 11-12, 2002.

Nakayama, H., H. Yamakuni, A. Nakayama, Y. Maeda, K. Imazumi, M. Matsuo, and S. Mutoh (2004). **Diphenidol has no actual broad antiemetic activity in dogs and ferrets.** *Journal of Pharmacological Sciences* 96(3): 301-306. ISSN: 1347-8613.

**Abstract:** Previous studies showed that diphenidol was effective on emetogens-induced pica, eating of non-nutritive substances, in rats, a model analogous to emesis in other species. We evaluated the actual antiemetic activity of diphenidol against four emetic stimuli in the dog and ferret, animals that possess an emetic reflex. In dogs, emetic responses to apomorphine were significantly prevented by diphenidol (3.2 mg/kg, i.v.), whereas diphenidol (3.2 mg/kg, i.v. x 2) showed a weak inhibition to the vomiting evoked by cisplatin. In ferrets, diphenidol (10 mg/kg, i.p.) exhibited a weak antiemetic activity on the emesis induced by copper sulfate and had no activity on emesis by loperamide. On the other hand, CP-122,721, a NK1-receptor antagonist, significantly reduced the emetic episodes to all four stimuli. These results suggest that the prediction of antiemetic activity of compounds in animals lacking an emetic reflex does not always correspond with actual antiemetic activity.

**Descriptors:** ferrets, dogs, antiemetics, piperidines pharmacology, vomiting, species specificity, chemically induced vomiting.

Nakayama, H., H. Yamakuni, M. Higaki, H. Ishikawa, K. Imazumi, M. Matsuo, and S. Mutoh (2005). **Antiemetic activity of FK1052, a 5-HT<sub>3</sub>- and 5-HT<sub>4</sub>-receptor antagonist, in *Suncus murinus* and ferrets.** *Journal of Pharmacological Sciences* 98(4): 396-403. ISSN: 1347-8613.

**Descriptors:** emesis, ferrets, *Suncus murinus*, antiemetic activity, FK1052, receptor antagonists, cancer chemotherapy, cisplatin-induced emesis, copper sulfate.

Oland, L.D., J.S. Davison, and K.a. Sharkey (2003). **Endocannabinoids inhibit emesis in the ferret.** *Digestive Disease Week Abstracts and Itinerary Planner* 2003: Abstract No. W1430.

**Descriptors:** ferret, endocannabinoid, antiemetics, sedative effect, inhibition of vomiting, endogenous cannabinoid receptor agonists, anandamide, 2- arachidonylglycerol (2-AG), noladin.

**Notes:** Digestive Disease 2003, FL, Orlando, USA; May 17-22, 2003.

Osinski, M.A., M.E. Uchic, T. Seifert, T.K. Shaughnessy, L.N. Miller, M. Nakane, B.F. Cox, J.D. Brioni, and R.B. Moreland (2005). **Dopamine D<sub>2</sub>, but not D<sub>4</sub>, receptor agonists are emetogenic in ferrets.** *Pharmacology, Biochemistry, and Behavior* 81(1): 211-219. ISSN: 0091-3057.

**Abstract:** Agents that activate the dopamine D<sub>2</sub>-like family of receptors elicit emesis in humans and other

species with a vomiting/emetic reflex; however, the lack of dopamine receptor subtype selective agonists has hampered an understanding of which dopamine D2-like receptor subtype(s) contributes to the emetic response. In this study, stable cell lines expressing the ferret dopamine D2-long (D2L) and D4 receptors were used to characterize known dopamine agonists via radioligand binding and calcium ion flux assays, while emetic activity of these dopamine receptor agonists was determined in male ferrets. Latencies to first emetic event, average number of emetic episodes, and stereotypical behaviors which may be indicative of nausea were also determined. Agonists at dopamine D1-like and D4 receptors had no emetic effect in ferrets. Conversely, stimulation of dopamine D2 and/or D3 receptors resulted in a robust emetic response characterized by a relatively short latency (<15 min) and multiple emetic events. Competitive antagonists of dopamine D2-like receptors (domperidone, haloperidol) dose-dependently blocked the emetic response to PNU95666E, a dopamine D2 receptor selective agonist. Thus, dopamine D2 and/or D3 receptor agonists elicit emesis, while dopamine D1/D5 or D4 receptor-selective agonists are devoid of emetic properties.

**Descriptors:** ferrets, dopamine agonists, chemically induced vomiting, protein binding.

Rudd, J.A., M.P. Ngan, M.K. Wai, A.G. King, J. Witherington, P.L. Andrews, and G.J. Sanger (2006). **Anti-emetic activity of ghrelin in ferrets exposed to the cytotoxic anti-cancer agent cisplatin.** *Neuroscience Letters* 392(1-2): 79-83. ISSN: 0304-3940.

**Abstract:** Emesis may be modulated via multiple mechanisms. The actions of ghrelin suggest an ability to couple an induction of hunger with preparation of the stomach for ingestion of food. Such a process might reduce any tendency to vomit, so an anti-emetic activity of ghrelin was investigated in the ferret cisplatin-induced emesis model. In controls, intra-peritoneal cisplatin (10 mg/kg) induced 41.4+/-8.4 episodes of emesis comprising 310.4+/-55.3 retches and 28.8+/-6.9 vomits during the 6h observation; the latency to onset of the first emetic episode was 108.9+/-4.8 min. Intra-peritoneal ghrelin (1mg/kg, split as a 30 min pre- and 30 min-post dose) did not induce a change in behaviour or modify cisplatin-induced emesis (p>0.05).

Intracerebroventricular (i.c.v.) administration (third ventricle) was achieved via a pre-implanted cannula. At the first emetic episode following cisplatin, ghrelin or vehicle (20 microl saline) was administered i.c.v. During the 30 min following the initial episode of emesis, control animals exhibited 18.0+/-2.6 emetic episodes comprising 160.3+/-24.1 retches and 13.8+/-2.7 vomits. Ghrelin 10 microg i.c.v. reduced the number of retches by 61.5% (p<0.05) and at a dose of 30 microg i.c.v. ghrelin reduced the number of episodes, individual retches and vomits by 74.4 (p<0.05), 80.4 (p<0.01), and 72.5% (p<0.05), respectively. At subsequent time periods there were no differences between ghrelin- or saline-treated animals (p>0.05). An ability of ghrelin to reduce emesis is consistent with a role in modulating gastro-intestinal functions and identifies a novel approach to the treatment of emesis.

**Descriptors:** ferrets, antiemetics, therapeutic use, antineoplastic agents, adverse effects, cisplatin, peptide hormones, therapeutic use, vomiting prevention, behavior, drug effects, disease models, dose response, drug interactions.

Sam, T.S., K.K. Kan, M.P. Ngan, J.A. Rudd, and J.H. Yeung (2003). **Action of metyrapone and tetracosactrin to modify cisplatin-induced acute and delayed emesis in the ferret.** *European Journal of Pharmacology* 466(1-2): 163-168. ISSN: 0014-2999.

**Abstract:** Cisplatin 5 mg/kg, i.p., induced an acute (day 1) and delayed (days 2 and 3) emetic response in the ferret that was used to investigate the potential anti-emetic activity of metyrapone and tetracosactrin and their potential interaction. The 11beta-hydroxylase enzymes inhibitor metyrapone 10-30 mg/kg, i.p., dose dependently potentiated the acute cisplatin-induced retching+vomiting response by up to 219% at the highest dose (P<0.001) but failed to affect significantly delayed emesis (P>0.05). The adrenocorticotrophic hormone (ACTH) mimetic tetracosactrin 0.1 mg/kg, i.m., antagonised significantly the acute and delayed emetic response by 98% (P<0.01) and 75% (P<0.001), respectively. The anti-emetic action of tetracosactrin on acute but not delayed emesis was prevented by combination with metyrapone 10 mg/kg, i.p. Tetracosactrin 0.1 mg/kg, i.m., failed to modify apomorphine (0.25 mg/kg, s.c.)-induced emesis. The potential anti-emetic mechanism of action of metyrapone and tetracosactrin to modulate emesis is discussed.

**Descriptors:** ferrets, emesis, antiemetics, antineoplastic agents, cisplatin, cosyntropin, metyrapone, chemically induced vomiting, apomorphine administration, intramuscular injections, intraperitoneal injections, subcutaneous injections.

Sato, A., R. Saito, H. Ariumi, K. Honda, Y. Takano, and H.O. Kamiya (2002). **Effects of cisplatin on monoamine levels in the area postrema and on emesis in ferrets.** *Japanese Journal of Pharmacology* 88(Supplement 1): 195P. ISSN: 0021-5198.

**Descriptors:** ferrets, cisplatin, monoamine levels, postrema, emesis, meeting abstract.

**Notes:** 75th Annual Meeting of the Japanese Pharmacological Society, Kumamoto, Japan; March 13-15, 2002.

Shintani, T., R.L. Mori, and B.J. Yates (2003). **Locations of neurons with respiratory-related activity in the ferret brainstem.** *Brain Research* 974(1-2): 236-242. ISSN: 0006-8993.

**Descriptors:** ferret, brain stem, respiratory related activity, coughing, emesis, location, quiet breathing, motoneurons.

Simoneau, I.I., M. Hamza, H.P. Mata, F. Porrecca, and T.P.J. Malan (2002). **Cannabinoids reduce morphine-induced emesis in ferrets.** *Anesthesiology Abstracts of Scientific Papers Annual Meeting(2000)*: Abstract No. 973.

**Online:** <http://www.asa-abstracts.com>

**Descriptors:** ferrets, emesis, morphine induced, cannabinoids, reduce, opioid analgesia, vomiting, meeting abstract.

**Notes:** 2000 Annual Meeting of the American Society of Anesthesiologists, San Francisco, CA, USA; October 16-18, 2000.

Tsuchiya, M., Y. Fujiwara, Y. Kanai, M. Mizutani, K. Shimada, O. Suga, S. Ueda, J.W. Watson, and A. Nagahisa (2002). **Anti-emetic activity of the novel nonpeptide tachykinin NK1 receptor antagonist ezlopitant (CJ-11,974) against acute and delayed cisplatin-induced emesis in the ferret.** *Pharmacology* 66(3): 144-152. ISSN: 0031-7012.

**Abstract:** The anti-emetic effects of a novel tachykinin NK(1) receptor antagonist, ezlopitant ((2S,3S-cis)-2-diphenylmethyl)- N-[(2-methoxy, 5-isopropylphenyl)methyl]-1-azabicyclo- [2.2.2]octan-3-amine), were investigated in ferrets. Ezlopitant inhibited [(3)H]substance P ([3]H)SP binding to the human, guinea pig, ferret and gerbil NK(1) receptors ( $K(i) = 0.2, 0.9, 0.6$  and  $0.5$  nmol/l, respectively), but had no affinity to NK(2) and NK(3) receptors up to 1 micromol/l. Ezlopitant also inhibited SP-induced contraction of guinea pig trachea with a  $pA(2)$  value of 7.8, but had no effects on the baseline tension and maximum contractile response. In ferrets, ezlopitant, either orally (0.03-3 mg/kg) or subcutaneously (0.3-3 mg/kg), prevented acute retching and vomiting responses induced by intraperitoneal injection of cisplatin (10 mg/kg). In addition, repeated subcutaneous injection of ezlopitant significantly inhibited delayed retching and vomiting responses that occurred in ferrets treated with the lower dose of cisplatin (5 mg/kg, i.p.). Ezlopitant (0.1-1 mg/kg, s.c.) also produced a dose-dependent inhibition of hindpaw tapping induced by intracerebroventricular injection of [Sar(9),Met(O(2))(11)]SP in gerbils, which is known to be mediated by NK(1) receptors in the brain. These findings indicate that ezlopitant is a potent and selective NK(1) receptor antagonist, and that it inhibits both acute and delayed emetic reactions induced by cisplatin in ferrets via acting on NK(1) receptors in the central nervous system. Copyright 2002 S. Karger AG, Basel

**Descriptors:** ferrets, antiemetics, benzylamines, bicyclo compounds, heterocyclic therapeutic use, cisplatin toxicity, neurokinin 1 antagonists, chemically induced vomiting, cricetinae, Gerbillinae, guinea pigs, protein binding receptors.

Van Sickle, M.D., L.D. Oland, K. Mackie, J.S. Davison, and K.A. Sharkey (2003). **Delta9-tetrahydrocannabinol selectively acts on CB1 receptors in specific regions of dorsal vagal complex to inhibit emesis in ferrets.** *American Journal of Physiology. Gastrointestinal and Liver Physiology* 285(3): G566-G576. ISSN: 0193-1857.

**Abstract:** The aim of this study was to investigate the efficacy, receptor specificity, and site of action of Delta9-tetrahydrocannabinol (THC) as an antiemetic in the ferret. THC (0.05-1 mg/kg ip) dose-dependently inhibited the emetic actions of cisplatin. The ED50 for retching was approximately 0.1 mg/kg and for vomiting was 0.05 mg/kg. A specific cannabinoid (CB)1 receptor antagonist SR-141716A (5 mg/kg ip) reversed the effect of THC, whereas the CB2 receptor antagonist SR-144528 (5 mg/kg ip) was ineffective. THC applied to the surface of the brain stem was sufficient to inhibit emesis induced by intragastric hypertonic saline. The site of action of THC in the brain stem was further assessed using Fos immunohistochemistry. Fos expression induced by cisplatin in the dorsal motor nucleus of the vagus (DMNX) and the medial subnucleus of the nucleus of the solitary tract (NTS), but not other subnuclei of the NTS, was significantly reduced by THC rostral to obex. At the level of the

obex, THC reduced Fos expression in the area postrema and the dorsal subnucleus of the NTS. The highest density of CB1 receptor immunoreactivity was found in the DMNX and the medial subnucleus of the NTS. Lower densities were observed in the area postrema and dorsal subnucleus of the NTS. Caudal to obex, there was moderate density of staining in the commissural subnucleus of the NTS. These results show that THC selectively acts at CB1 receptors to reduce neuronal activation in response to emetic stimuli in specific regions of the dorsal vagal complex.

**Descriptors:** ferrets, antiemetics, medulla oblongata, tetrahydrocannabinol, vagus nerve physiology, vomiting, area postrema, cisplatin, cannabinoid receptors, tissue distribution.

Yamakuni, H., H. Nakayama, S. Matsui, K. Imazumi, M. Matsuo, and S. Mutoh (2006). **Inhibitory effect of zacopride on Cisplatin-induced delayed emesis in ferrets.** *Journal of Pharmacological Sciences* 101(1): 99-102. ISSN: 1347-8613.

**Abstract:** We evaluated the antiemetic effect of zacopride, a potent 5-HT<sub>3</sub>-receptor antagonist with 5-HT<sub>4</sub>-receptor agonist properties, on delayed emesis caused by cisplatin (5 mg/kg, i.p.) in ferrets, compared with granisetron, a selective 5-HT<sub>3</sub>-receptor antagonist. Multiple intravenous injections of zacopride at 1 mg/kg, a dose that completely inhibited acute emesis caused by cisplatin (10 mg/kg, i.v.), significantly reduced delayed emesis. Granisetron (3.2 mg/kg) also reduced delayed emesis but this failed to reach statistical significance. The present study suggests that a combined 5-HT<sub>3</sub>-receptor antagonist/5-HT<sub>4</sub>-receptor agonist, like zacopride, may be useful against both acute and delayed emesis induced by cancer chemotherapy.

**Descriptors:** antiemetics, antineoplastic agents, benzamides, serotonin antagonists, vomiting, ferrets, granisetron, time factors, chemically induced vomiting.

Yamakuni, H., H. Sawai Nakayama, K. Imazumi, Y. Maeda, M. Matsuo, T. Manda, and S. Mutoh (2002).

**Resiniferatoxin antagonizes cisplatin-induced emesis in dogs and ferrets.** *European Journal of Pharmacology* 442(3): 273-278. ISSN: 0014-2999.

**Abstract:** We evaluated the antiemetic activity of resiniferatoxin, an ultrapotent capsaicin analogue, on cisplatin- and apomorphine-induced emesis in dogs, and on cisplatin-induced acute and delayed emesis in ferrets. In the dog, resiniferatoxin (10 microg/kg, s.c.) 30 min before the injection of cisplatin markedly prevented acute emesis induced by cisplatin. When animals were given resiniferatoxin (10 microg/kg, s.c.) 24 h prior to cisplatin, the emesis was still inhibited, but not significantly. Resiniferatoxin (10 microg/kg, s.c.) 30 min before the administration of apomorphine also significantly reduced the emetic responses induced by apomorphine in dogs. In the ferret, resiniferatoxin (10 microg/kg, s.c.) 30 min prior to cisplatin completely inhibited acute emesis caused by cisplatin (10 mg/kg, i.p.). When ferrets were given resiniferatoxin (10 microg/kg, s.c.) 16 h prior to cisplatin, the emesis was still significantly inhibited. Cisplatin (5 mg/kg, i.p.) induced both acute (0-24 h) and delayed (24-72 h) phase emesis, and a single injection of resiniferatoxin (10 microg/kg, s.c.) at 36 h after cisplatin significantly reduced subsequent emetic responses during the 36-72 h period. These results suggest that resiniferatoxin-related vanilloids may be useful drugs against both acute and delayed emesis induced by cancer chemotherapy.

**Descriptors:** ferrets, dogs, antineoplastic agents, cisplatin, diterpenes, vomiting, antineoplastic agents, antiparkinson agents, apomorphine, cisplatin toxicity.

Yanagihara, M., T. Mori, T. Ohonishi, H. Fukuda, N. Furukawa, and J. Col (2004). **Investigation of neuronal circuit for induction of vomiting in the ferret.** *Anatomical Science International* 79(August): 376. ISSN: 1447-6959.

**Descriptors:** ferret, vomiting, neuronal circuit, inducing vomiting.

**Notes:** 16th International Congress of the IFAA (International Federation of Associations of Anatomists) and the 109th Annual Meeting of the Japanese Association of Anatomists, Kyoto, Japan; August 22-27, 2004.

Yoshikawa, T. and N. Yoshida (2002). **Effect of 6-hydroxydopamine treatment in the area postrema on morphine-induced emesis in ferrets.** *Japanese Journal of Pharmacology* 89(4): 422-425. ISSN: 0021-5198.

**Abstract:** To investigate the role of catecholamine release in emesis, we examined the effects of pretreatment with 6-hydroxydopamine (6-OH-DA) administered into the area postrema in morphine-induced emesis in ferrets. In the 6-OH-DA pre-treated animals, the latency to the first emetic response induced by morphine hydrochloride (1.0 mg/kg, s.c.) was significantly prolonged and the number of retches and emetic episodes was markedly reduced. In the medulla oblongata, the levels of dopamine and homovanilic acid were reduced by 6-

OH-DA pretreatment. These results suggest that catecholamine release in the medulla oblongata, mainly dopamine release, may play an important role in morphine-induced emesis in ferrets.

**Descriptors:** ferrets, postrema drug effects, morphine toxicity, oxidopamine, chemically induced vomiting, area postrema metabolism.

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National Agricultural Library



## Information Resources on the Care and Welfare of Ferrets

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### Enrichment

Fisher, P. (2005). **Environmental enrichment for ferrets.** *Exotic DVM* 6(6): 20. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, behavior, animal welfare, housing, enrichment, environment, methods.

Reinhardt, V. and A. Reinhardt (2006). *Database on Refinement of Housing and Handling Conditions and Environmental Enrichment for Animals Kept in Laboratories: Rodents, Rabbits, Cats, Dogs, Ferrets, Farm Animals, Horses, Birds Fishes, Amphibians and Reptiles.*, [Online Database]

**Online:** <http://labanimals.awionline.org/SearchResultsSite/refine.aspx>

**NAL Call Number:** SF406.3

**Descriptors:** laboratory animals housing databases, laboratory animals environmental enrichment databases, databases, enrichment, housing.

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## Information Resources on the Care and Welfare of Ferrets

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# Feeding / Nutrition / Metabolism

Fekete, S.G., K. Fodor, A. Prohaczik, and E. Andrasofszky (2005). **Comparison of feed preference and digestion of three different commercial diets for cats and ferrets.** *Journal of Animal Physiology and Animal Nutrition* 89(3-6): 199-202. ISSN: 0931-2439.

**Abstract:** Diet preference and digestibility experiments were conducted using a total of 10 cats and 10 ferrets. The composition of the three different kinds of dry cat feed was as follows (each data are given in dry matter, DM): (i) normal diet (N): 95.3% DM, 33.7% crude protein (CP), 20.4% ether extract (EE), 37.6% nitrogen-free extract (NFE); (ii) 'light diet' (L): 94.2% DM, 31.6% CP, 10.7% EE, 52.2% NFE; (iii) 'veterinary diet' (D): 94.57% DM, 38.7% CP, 9.6% EE, 47.2% NFE. During the period of the preference test, the average daily dry matter intake (calculated with the mean of the three diets: 94.7% DM) was 98.0, 15.0 and 16.7 g DM in cats and 25.0, 7.3 and 8.1 g DM in ferrets. The preference rates of the three different diets, expressed in percentage of their total consumption, were as follows: 60.4% N (54.4 g DM), 12.4% L (12.1 g DM) and 27.2% D (26.6 g DM) in cats, and 46.2% N (11.6 g DM), 29.9% L (7.5 g DM) and 23.9% D (6.0 g DM) in ferrets. This indicates that cats and ferrets have a clear preference for diets of higher fat content. In all three diets, the digestibility of CP was significantly ( $p < 0.05$ ) lower ( $70.1 \pm 5.4$  vs.  $75.9 \pm 5.8$ ) while that of EE was significantly ( $p < 0.05$ ) higher ( $95.6 \pm 1.5$  vs.  $89.4 \pm 5.3$ ) in ferrets than in cats. The average digestible/metabolizable energy (DE/ME) ratio of feeds turned to be 95.6% for cats and 90.6% for the ferrets. From the data one can conclude that the ferret cannot be used as a model animal for cats either for preference or digestibility studies.

**Descriptors:** ferrets, animal feed, cats, digestion physiology, food preferences, nutrition, dietary fats, dietary proteins.

Harrington, L.A., D.E. Biggins, and A.W. Alldredge (2003). **Basal metabolism of the Black-footed ferret (*Mustela nigripes*) and the Siberian polecat (*M. eversmannii*).** *Journal of Mammalogy* 84(2): 497-504. ISSN: 0022-2372.

**Abstract:** Black-footed ferrets (*Mustela nigripes*) and Siberian polecats (*M. eversmannii*) are medium-sized (about 1 kg) mustelids with similar ecological and morphological characteristics. We measured basal metabolic rates (BMR) for both species. In contrast with the commonly stated belief that mustelids have relatively high mass-specific BMR, neither the BMR of ferrets nor that of polecats in winter was greater than standard allometric predictions for all mammals. As suggested by previous authors, we believe that our relatively lower measurements for BMR are due to our efforts to minimize stress during the experimental procedure. These results support the contention that BMR in mustelids is no different from what is expected of mammals of this body mass. Seasonal differences were found in polecat BMR (higher in summer) but not in ferret BMR. Reasons for this interspecific difference may relate to differences in natural histories of these species. Reprinted by permission of the publisher.

**Descriptors:** black-footed ferret, Siberian polecat, basal metabolism, body mass, seasonal differences.

Liu, C., R.M. Russell, and X.D. Wang (2004). **Low dose beta-carotene supplementation of ferrets attenuates smoke-induced lung phosphorylation of JNK p38 MAPK and p53 proteins.** *Journal of Nutrition* 134(10): 2705-2710. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Descriptors:** ferrets, proteins, beta carotene, supplementation, smoke induced lung phosphorylation, low dose.

Liu, C., R.M. Russell, and X.D. Wang (2006). **Lycopene supplementation prevents smoke-induced changes in p53, p53 phosphorylation, cell proliferation, and apoptosis in the gastric mucosa of ferrets.** *Journal of Nutrition* 136(1): 106-111. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Abstract:** Cigarette smoking increases the risk for gastric cancer. Higher intakes or blood levels of lycopene are associated with a decreased risk of gastric cancer. However, the biological mechanisms by which lycopene may protect against gastric carcinogenesis are poorly understood. We evaluated the effects of lycopene supplementation on smoke-induced changes in protein levels of p53, p53 target genes (p21<sup>Waf1/Cip1</sup> and Bax-1), cell proliferation, and apoptosis in the gastric mucosa of ferrets. Ferrets were assigned to cigarette smoke exposure or to no exposure and to no, low-dose, or high-dose lycopene supplementation (2 x 3 factorial design) for 9 wk. Lycopene concentrations were significantly elevated in a dose-dependent manner in the gastric mucosa of ferrets supplemented with lycopene alone, but were markedly reduced in ferrets supplemented with lycopene and exposed to smoke. Although ferrets were given lycopene containing 95% all-trans isomers, cis isomers were the predominant forms in the gastric mucosa. Total p53 and phosphorylated p53 levels were greater in ferrets exposed to smoke alone than in all other groups. Levels were [approximately]300 and 500% of the controls, respectively. However, smoke-elevated total p53 and phosphorylated p53 were markedly attenuated by both doses of lycopene. p21<sup>Waf1/Cip1</sup>, Bax-1, and cleaved caspase 3 were substantially decreased, whereas cyclin D1 and proliferating cellular nuclear antigen (PCNA) were increased in ferrets exposed to smoke alone. Lycopene prevented smoke-induced changes in p21<sup>Waf1/Cip1</sup>, Bax-1, cleaved caspase 3, cyclin D1, and PCNA in a dose-dependent fashion. These data indicate that lycopene may prevent smoke exposure-induced changes in p53, p53 phosphorylation, p53 target genes, cell proliferation, and apoptosis in the gastric mucosa of ferrets.

**Descriptors:** ferrets, animal disease models, smoking habit, lycopene, dietary supplements, protein phosphorylation, cell proliferation, apoptosis, human health, gastric mucosa, cigarettes, gastric cancer, human diseases, chemoprevention, gene expression, proliferating cell nuclear antigen, cyclins, animal proteins.

Nieminen, P., A.M. Mustonen, P. Lindstrom Seppa, J. Asikainen, H. Mussalo Rauhamaa, and J.V.K. Kukkonen (2002). **Phytosterols act as endocrine and metabolic disruptors in the European polecat (*Mustela putorius*).** *Toxicology and Applied Pharmacology* 178(1): 22-28. ISSN: 0041-008X.

**NAL Call Number:** 391.8 T662

**Descriptors:** polecats, phytosterols, oral administration, blood plasma, estradiol, thyroid hormones, somatoliberin, hormones, carbohydrate metabolism, liver, kidneys, glycogen, glucose 6 phosphate, triacylglycerol lipase, glycogen phosphorylase, enzyme activity, blood lipids, low density lipoprotein, high density lipoprotein, cholesterol.

Raila, J., C. Gomez, and F.J. Schweigert (2002). **The ferret as a model for vitamin A metabolism in carnivores.** *Journal of Nutrition* 132(6 Suppl 2): 1787s-1789s. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Descriptors:** ferret metabolism, vitamin A, diet, kidney metabolism, liver metabolism, retinol binding proteins, animal models.

Rosenthal, K.L. (2006). **Feeding the hypoglycemic ferret.** In: *Small animal and exotics Proceedings of the North American Veterinary Conference. January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1766.

**Online:** <http://www.tnava.org>

**Descriptors:** feeding, ferret feeding, hypoglycemia.

Sundaresan, P.R., P. Marmillot, Q.H. Liu, G.V. Mitchell, E. Grundel, and M.R. Lakshman (2005). **Effects of dietary taurocholate, fat and protein on the storage and metabolism of dietary beta-carotene and alpha-tocopherol in ferrets.** *International Journal for Vitamin and Nutrition Research* 75(2): 133-141.

**NAL Call Number:** 389.8 Z33

**Abstract:** Dietary factors affecting tissue storage of beta-carotene (BC), alpha-tocopherol (alpha-T), and retinol (ROL) in mammals include taurocholate, protein, and fat. Few studies have examined the effects of these factors on the storage of BC, retinyl esters, and alpha-T in a mammalian system that is similar to humans. The main objective of the study was to investigate the effects of taurocholate (TC), fat, and protein on the absorption and metabolism of BC and alpha-T in ferret tissues. Three 4-week experiments were conducted using groups of 5-6 ferrets per treatment. All diets contained 0.2% BC. In Experiment 1, taurocholate was fed at concentrations of 0, 0.5, or 1%. Effects of two concentrations of dietary fat (6 and 23%) and three concentrations of protein (10, 20, and 40%) were also studied in Experiments 2 and 3, respectively. Tissues were analyzed for BC, retinoids, and alpha-T by high-pressure liquid chromatography (HPLC). Taurocholate enhanced hepatic and plasma concentrations of BC (2.3- to 3-fold), retinyl palmitate [(RP) 3.2- to 9.5-fold], retinyl stearate [(RS) 2.9- to 6- fold], and hepatic alpha-T (6- to 13- fold) at  $p < 0.05$ . High-fat diets elevated hepatic BC, RP, RS, and retinyl linoleate (RL) concentrations (2- to 3.6-fold,  $p < 0.05$ ). In contrast, high-protein diets lowered hepatic RL 1.8-fold and alpha-T 8-fold ( $p < 0.05$ ). Our results indicate the importance of taurocholate, fat, and protein in achieving adequate levels of vitamins A and E in mammals.

**Descriptors:** ferrets, dietary fats, dietary proteins, taurocholic acid, alpha tocopherol, beta carotene, liquid diet, liver chemistry, blood, nutrition.

Triantafyllou, A., D. Fletcher, and J. Scott (2005). **Organic secretory products, adaptive responses and innervation in the parotid gland of ferret: A histochemical study.** *Archives of Oral Biology* 50(9): 769-777. ISSN: 0003-9969.

**NAL Call Number:** RK1.A6989

**Abstract:** To qualify cellular events of possible pathophysiological significance in the parotid of ferret, tissue obtained post-mortem from mature animals of either sex was examined by light microscopical histochemistry for calcium, protein, amino acids, mucosubstances and hydrolases, and by neurohistology. Calcium was localised in acinar cells replete with granules containing protein, disulphides and usually carboxylated mucosubstances. Acid phosphatase activity was basally concentrated in the acinar cells. The granular luminal region of striated ductal cells showed protein, tryptophan, disulphides, neutral mucosubstances, and E600-sensitive esterase and Naphthol AS-D chloroacetate esterase activities, whereas their basal region showed acid phosphatase activity. Strong periluminal activity of acid phosphatase and E600-resistant esterase characterised the collecting ducts. Cholinesterase activity was associated with an extensive network of nerve fibres embracing parenchyma. Catecholamine fluorescence was not seen. beta-glucuronidase reactive macrophages abounded in the interstices. The results suggest that while the acini in the parotid of ferret secrete polyionic glycoproteins, shielded by calcium, the striated ducts secrete tryptophan-rich products comprising neutral glycoproteins and showing proteolytic activity. Innervation is of the cholinergic type and parenchymal lysosomal activity, possibly related to autophagy of stored secretory products and heterophagy of luminal material, is brisk. Macrophages contribute to maintaining the glandular microenvironment, wherein secretory activity appears to be lethargic.

**Descriptors:** ferrets, metabolism, phosphatase analysis, calcium analysis, disulfides analysis, anatomy, histology, hydrolases metabolism, nerve fibers, parotid gland cytology, innervation.

Wang, X.D. (2005). **Can smoke-exposed ferrets be utilized to unravel the mechanisms of action of lycopene.** *Journal of Nutrition* 135(8): 2053S-2056S. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Descriptors:** tomato products, lycopene, anticarcinogenic activity, lung cancer, ferrets, animal models, smoking habit, mechanism of action, dosage, metabolites, blood chemistry, lungs, cell proliferation, epidemiology.

**Notes:** In the special section: "Promises and perils of lycopene/tomato supplementation and cancer prevention." Presented at a conference held February 17-18, 2005, Bethesda, Maryland.

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## Information Resources on the Care and Welfare of Ferrets

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### Neoplasia / Tumors

Angella, P.R.A., K.A. Margit, and H. Gyula (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei -irodalmi attekintes 4. Endokrin eredetu bokelvaltozasok, hormonalis megbetegedések. [Reproduction, genital malfunctions and endocrine disorders of domestic ferrets (*Mustela putorius furo*): Literature review. 4. Endocrine skin lesions, hormonal diseases]. *Magyar Allatorvosok Lapja* 126(9): 553-560. ISSN: 0025-004X.**

**Descriptors:** endocrine system, tumor biology, endocrine disease, pathology, metabolic disease, adrenal, metabolic disease, epidemiology, neoplastic disease.

**Language of Text:** Hungarian.

Bielinska, M., S. Kiiveri, H. Parviainen, S. Mannisto, M. Heikinheimo, and D.B. Wilson (2006). **Gonadectomy-induced Adrenocortical Neoplasia in the Domestic Ferret (*Mustela putorius furo*) and Laboratory Mouse.** *Veterinary Pathology* 43(2): 97-117. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Sex steroid-producing adrenocortical adenomas and carcinomas occur frequently in neutered ferrets, but the molecular events underlying tumor development are not well understood. Prepubertal gonadectomy elicits similar tumors in certain inbred or genetically engineered strains of mice, and these mouse models shed light on tumorigenesis in ferrets. In mice and ferrets, the neoplastic adrenocortical cells, which functionally resemble gonadal steroidogenic cells, arise from progenitors in the subcapsular or juxtamedullary region. Tumorigenesis in mice is influenced by the inherent susceptibility of adrenal tissue to gonadectomy-induced hormonal changes. The chronic elevation in circulating luteinizing hormone that follows ovariectomy or orchietomy is a prerequisite for neoplastic transformation. Gonadectomy alters the plasma or local concentrations of steroid hormones and other factors that affect adrenocortical tumor development, including inhibins, activins, and Mullerian inhibiting substance. GATA-4 immunoreactivity is a hallmark of neoplastic transformation, and this transcription factor might serve to integrate intracellular signals evoked by different hormones. Synergistic interactions among GATA-4, steroidogenic factor-1, and other transcription factors enhance expression of inhibin- $\alpha$  and genes critical for ectopic sex steroid production, such as cytochrome P450 17 $\alpha$ -hydroxylase/17,20 lyase and aromatase. Cases of human adrenocortical neoplasia have been linked to precocious expression of hormone receptors and to mutations that alter the activity of G-proteins or downstream effectors. Whether such genetic changes contribute to tissue susceptibility to neoplasia in neutered ferrets and mice awaits further study.

**Descriptors:** ferrets, mice, ovariectomy, castration, complications, adrenal cortex, neoplasms, carcinogenesis, steroidogenesis, steroid hormones, luteinizing hormone (LH), transcription factors, literature reviews, orchietomy, adrenal tumors, tumor development.

Buchanan, K.C. and D.A. Belote (2003). **Pancreatic islet cell tumor in a domestic ferret.** *Contemporary Topics in Laboratory Animal Science* 42(6): 46-48. ISSN: 1060-0558.

**NAL Call Number:** SF405.5.A23

**Abstract:** A 5-year-old castrated male ferret began to exhibit signs of episodic lethargy, hindlimb weakness, and

ataxia along with mild to moderate weight loss. Serial blood glucose measurements revealed persistent hypoglycemia. The animal was euthanized and a necropsy performed. Discrete pancreatic nodules were discovered and submitted for histopathologic analysis. One of the nodules was found to contain pancreatic islet cell tumors; other areas contained foci of islet cell and acinar hyperplasia. Pancreatic islet cell tumors, commonly referred to as insulinomas, are common tumors in ferrets and typically occur in middle-aged and older animals. These animals, when properly diagnosed, can be managed either medically or surgically or, often, by a combination of medical and surgical treatments, and their lives greatly extended.

**Descriptors:** ferrets, insulinoma, pancreas, pancreatic neoplasms, hypoglycemia, insulinoma, photomicrography.

Darby, C. and V. Ntavlourou (2006). **Hepatic hemangiosarcoma in two ferrets (*Mustela putorius furo*)**. *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 689-694. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Two ferrets were presented to the authors' clinic. Hemoperitoneum was diagnosed in one ferret, and an abdominal mass was palpated in the other. One ferret was euthanized and necropsied, and one ferret underwent exploratory laparotomy and liver lobectomy. In both cases, the histopathologic diagnosis was hepatic hemangiosarcoma.

**Descriptors:** ferrets, hemangiosarcoma, hepatic, abdominal mass, laparotomy, diagnosis, liver lobectomy.

De Voe, R.S., L. Pack, and C.B. Greenacre (2002). **Radiographic and CT imaging of a skull associated osteoma in a ferret**. *Veterinary Radiology & Ultrasound* 43(4): 346-348. ISSN: 1058-8183.

**NAL Call Number:** SF757.8.A4

**Descriptors:** ferrets, case reports, skull, radiography, computed tomography, diagnostic value, biopsy, neoplasms, mandible.

Defalque, V. and C. Carozzo (2003). **Cancerologie du furet. Insulinome chez un furet male castré age de cinq ans. [Oncology of ferrets. Insulinoma in a five-year old castrated male ferret]**. *Le Point Veterinaire* 234: 64-68, 1283. ISSN: 0335-4997.

**Abstract:** Un furet age de cinq ans est refere pour des episodes de troubles neurologiques recurrences associes a du ptyalisme depuis trois semaines. Les examens biochimiques mettent en evidence une hypoglycemie. Une echographie abdominale revele l' existence d' un nodule pancreatique. Un traitement medical preoperatoire est instaure, mais l' animal est presente en urgence le lendemain en etat de crise hypoglycémique. Apres stabilisation de l' etat general, une pancreatectomie partielle est realisee. L' analyse histopathologique conclut a un adenome des cellules des ilots de Langerhans pour lequel le pronostic est bon. Le diagnostic de l' insulinome chez les carnivores domestiques repose essentiellement sur des elements epidemiologiques et cliniques, la satisfaction a un certain nombre de criteres, et le recours a des examens biochimiques et echographiques.

**Descriptors:** ferrets, pet animals, pancreas, adenoma, surgical operations, animal glands, digestive system, Mustelidae, neoplasms.

**Language of Text:** French.

Eatwell, K. (2004). **Two unusual tumours in a ferret (*Mustela putorius furo*)**. *Journal of Small Animal Practice* 45(9): 454-459. ISSN: 0022-4510.

**NAL Call Number:** 41.8 J8292

**Abstract:** This case report describes the clinical history, diagnosis and treatment of a ferret with a tumour of the right adrenal gland and insulinomas of the pancreas. Histopathology of both lesions confirmed the diagnoses. Clinical signs of the adrenal gland tumour were a swollen vulva, overgrooming, sexual activity and pruritus. The clinical signs suggesting insulinomas were collapse of the ferret, disorientation and ptyalism. A low blood glucose level assisted the diagnosis of insulinomas. This is believed to be the first reported case of concurrent insulinomas and adrenal gland tumour in a ferret in the United Kingdom.

**Descriptors:** ferrets, adenoma, adrenal gland neoplasms, insulinoma, pancreatic neoplasms, treatment outcome, surgery.

Garcia, A., S.E. Erdman, S. Xu, Y. Feng, A.B. Rogers, M.D. Schrenzel, J.C. Murphy, and J.G. Fox (2002).

**Hepatobiliary inflammation, neoplasia, and argyrophilic bacteria in a ferret colony**. *Veterinary Pathology*

39(2): 173-179. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Hepatobiliary disease was diagnosed in eight of 34 genetically unrelated cohabitating pet ferrets (*Mustela putorius furo*) during a 7-year period. The eight ferrets ranged in age from 5 to 8 years and exhibited chronic cholangiohepatitis coupled with cellular proliferation ranging from hyperplasia to frank neoplasia. Spiral-shaped argyrophilic bacteria were demonstrated in livers of three ferrets, including two with carcinoma. Sequence analysis of a 400-base pair polymerase chain reaction product amplified from DNA derived from fecal bacteria from one ferret demonstrated 98% and 97% similarity to *Helicobacter cholecystus* and *Helicobacter* sp. strain 266-1, respectively. The clustering of severe hepatic disease in these cohabitating ferrets suggests a possible infectious etiology. The role of *Helicobacter* species and other bacteria in hepatitis and/or neoplasia in ferrets requires further study.

**Descriptors:** ferrets, helicobacter infections, *Helicobacter pylori*, liver diseases, bile duct neoplasms, biliary tract diseases, cholangiocarcinoma, cystadenoma, bacterial DNA, hepatitis, hyperplasia, immunohistochemistry, liver microbiology.

Graham, J., J. Fidel, and M. Mison (2006). **Rostral maxillectomy and radiation therapy to manage squamous cell carcinoma in a ferret.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 701-706. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** A 4-year-old, male, neutered ferret presented with squamous cell carcinoma of the right maxillary region associated with the tissues surrounding the upper canine tooth. A rostral maxillectomy was performed to excise the mass. Histopathologic examination showed questionable margins of tumor removal. Approximately 2 months after surgery, the ferret received a course of radiation therapy and is currently being monitored for tumor regrowth.

**Descriptors:** ferret, squamous cell carcinoma, radiation therapy, rostral maxillectomy.

Hanley, C.S., G.H. Wilson, P. Frank, D.K. James, K.P. Carmichael, D. Pesti, and B. Ritchie (2004). **T cell lymphoma in the lumbar spine of a domestic ferret (*Mustela putorius furo*).** *Veterinary Record* 155(11): 329-332. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Abstract:** A 22-month-old castrated male ferret developed acute pelvic limb paresis. Radiographs and computed tomography revealed a soft tissue mass with associated bony lysis of L5, and ultrasound-guided fine needle aspirates suggested that it was a lymphoma. Treatment with prednisone at immunosuppressive doses did not produce any detectable improvement in the ferret's clinical signs and it became moribund less than two weeks after they developed. A postmortem biopsy confirmed the presence of a lymphoma which had invaded the vertebral bone. No viruses were detected by cell culture, or electron microscopy.

**Descriptors:** ferrets, lumbar vertebrae, t cell lymphoma, spinal neoplasms, blood chemical analysis, x ray computed tomography, case study.

Hess, L. (2005). **Ferret lymphoma: The old and the new.** *Seminars in Avian and Exotic Pet Medicine* 14(3): 199-204. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, lymphoma, spleen, liver, lymph nodes, kidneys, etiology, potential causes, review, clinical signs, treatment options.

**Notes:** In the special issue: Oncology.

Jones, Y., A. Wise, R. Maes, and M. Kiupel (2006). **Peloid hepatocellular carcinoma in a domesticated ferret (*Mustela putorius furo*).** *Journal of Veterinary Diagnostic Investigation* 18(2): 228-231. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** Peloid hepatocellular carcinoma was diagnosed in a domesticated ferret (*Mustela putorius furo*). The diagnosis was made using immunohistochemical analysis, histologic examination, and the accepted classification schemes based on histomorphologic features. Bilateral, adrenocortical hyperplasia also was evident. Speculation about a possible association between the variant of hepatocellular neoplasia diagnosed in this animal and its adrenal pathologic changes was done.

**Descriptors:** domesticated ferret, peliod hepatocellular carcinoma, diagnosis.

Kawaguchi, H., N. Miyoshi, M. Souda, H. Maeda, H. Kawashima, K. Gejima, K. Uchida, Y. Umekita, and H. Yoshida (2006). **Renal Adenocarcinoma in a Ferret.** *Veterinary Pathology* 43(3): 353-356. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** A spontaneous case of renal tumor was observed in a 7-year-old ovariectomized female pet ferret (*Mustela putorius furo*). Clinical signs included exhaustion, emaciation, anorexia, and stooping position. At necropsy, a solid and cystic mass replaced the left kidney and adrenal gland. The tumor was composed of pleomorphic epithelial cells with a large number of giant cells. Metastases were recognized in the lung, liver, greater omentum, right renal pelvis, and systemic lymph nodes. Immunohistochemical stains revealed that the tumor cells were positive for CD10, cytokeratin (CAM 5.2), and Ki-67 (MIB-1). On the basis of morphologic and immunohistochemical features, the tumor was diagnosed as a pleomorphic renal adenocarcinoma. This type of neoplasm is very rare in all species and has never been reported in a ferret.

**Descriptors:** *Mustela putorius*, case studies, kidney diseases, adenocarcinoma, metastasis, histopathology.

Lair, S., I.K. Barker, K.G. Mehren, and E.S. Williams (2006). **Renal Tubular-cell Neoplasms in Black-footed Ferrets (*Mustela nigripes*)-38 Cases.** *Veterinary Pathology* 43(3): 276-280. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Thirty-eight cases of renal tubular cell neoplasms were diagnosed in 184 captive, adult (>1-year-old), black-footed ferrets (*Mustela nigripes*) examined from 1985 to 1996. This prevalence (20.7%) is one of the highest reported for this neoplasm in a population of animals. These tumors rarely metastasized (1/38), and usually were incidental postmortem findings, associated clinical disease being present in only 3 (8%) of the 38 cases. The prevalence of renal tubular cell neoplasms found at postmortem examination increased linearly with age, up to 67% in ferrets >8 years old. Both males (prevalence = 19%) and females (prevalence = 24%) were affected. Multiple renal tumors were common, and seven ferrets (18.4% of affected animals) had bilateral tumors. The cause of this neoplastic syndrome could not be determined. Since most of the animals affected by this condition were in their postreproductive years of life, the impact of this neoplastic syndrome on the captive propagation of this species is negligible.

**Descriptors:** *Mustela nigripes*, kidney diseases, neoplasms, animal age, disease prevalence, disease course, zoo animals, endangered species.

Lair, S., I.K. Barker, K.G. Mehren, and E.S. Williams (2002). **Epidemiology of neoplasia in captive black-footed ferrets (*Mustela nigripes*), 1986-1996.** *Journal of Zoo and Wildlife Medicine* 33(3): 204-223. ISSN: 1042-7260.

**NAL Call Number:** SF601.J6

**Abstract:** The epidemiology of neoplastic disease was studied retrospectively in the captive population of black-footed ferrets (*Mustela nigripes*). Postmortem reports were reviewed and archived tissues examined from 184 of the 227 adult (>1 yr old) black-footed ferrets that died from the beginning of the current captive propagation program in late 1985 to the end of 1996. A total of 185 neoplasms, of 28 distinct phenotypes, were seen in 102 (55.4%) of these ferrets. There was more than one tumor type present in 51 ferrets. Tumors of the apocrine glands (28.3%), renal tubular neoplasms (20.7%), and biliary cystadenoma or carcinoma (20.1%) were the most common neoplasms. The probability of developing most types of neoplasms increased with age. Neoplasms of the apocrine glands were more common in males and may be hormonally influenced. The unusually high prevalence of biliary cystadenocarcinoma may be secondary to the common occurrence of intrahepatic biliary cysts in this population. Although neoplasia is an important cause of mortality in captive adult black-footed ferrets, its impact on captive propagation of the species, and on the wild population, is probably limited because clinically significant tumors are encountered almost exclusively in postreproductive ferrets (>3 yr old) and because ferrets released into their natural habitat rarely reach susceptible age.

**Descriptors:** black-footed ferrets, neoplasms, age distribution, logistic models, neoplasms classification and epidemiology, prevalence, retrospective studies, Wyoming, epidemiology.

Liu, C., F. Lian, D.E. Smith, R.M. Russell, and X.D. Wang (2003). **Lycopene supplementation inhibits lung squamous metaplasia and induces apoptosis via up-regulating insulin-like growth factor-binding protein 3 in cigarette smoke-exposed ferrets.** *Cancer Research* 63(12): 3138-3144. ISSN: 0008-5472.

**Abstract:** Higher intake of lycopene is related to a lower risk of lung cancer in human studies. Lung cancer risk is associated with higher plasma levels of insulin-like growth factor I (IGF-I) and/or lower levels of IGF-binding protein 3 (IGFBP-3). However, little is known regarding whether lycopene can inhibit cigarette smoke-induced lung carcinogenesis through modulation of IGF-I/IGFBP-3, cell proliferation, and apoptosis. We investigated the effects of lycopene supplementation at a low dose (1.1 mg/kg/day, which is equivalent to an intake of 15 mg/day in humans) and a high dose (4.3 mg/kg/day, which is equivalent to 60 mg/day in humans) on plasma IGF-I/IGFBP-3 levels, histopathological changes, proliferating cellular nuclear antigen (PCNA) expression, BAD phosphorylation, and apoptosis (caspase 3 assay) in lungs of ferrets with or without cigarette smoke exposure for 9 weeks. We found that ferrets supplemented with lycopene and exposed to smoke had significantly higher plasma IGFBP-3 levels ( $P < 0.01$ ) and a lower IGF-I/IGFBP-3 ratio ( $P < 0.01$ ) than ferrets exposed to smoke alone. Both low- and high-dose lycopene supplementations substantially inhibited smoke-induced squamous metaplasia and PCNA expression in the lungs of ferrets. No squamous metaplasia or PCNA overexpression were found in the lungs of control ferrets or those supplemented with lycopene alone. Furthermore, cigarette smoke exposure greatly increased BAD phosphorylation at both Ser(136) and Ser(112) and significantly decreased cleaved caspase 3 in the lungs of ferrets, as compared with controls. The elevated phosphorylation of BAD and down-regulated apoptosis induced by cigarette smoke in the lungs of ferrets was prevented by both low- and high-dose lycopene supplementations. Lycopene levels were increased in a dose-dependent manner in both plasma and lungs of ferrets supplemented with lycopene alone. However, lycopene levels were markedly lower in both plasma and lungs of ferrets supplemented with lycopene and exposed to smoke. Furthermore, smoke exposure increased cis isomers (26% for 13-cis and 22% for 9-cis) of lycopene in the lungs of ferrets, compared with that of ferrets supplemented with lycopene alone (20% for 13-cis and 14% for 9-cis). In conclusion, lycopene may mediate its protective effects against smoke-induced lung carcinogenesis in ferrets through up-regulating IGFBP-3 and down-regulating phosphorylation of BAD, which promote apoptosis and inhibit cell proliferation.

**Descriptors:** ferrets, anticarcinogenic agents, apoptosis, carotenoids, adverse effects of smoke, anticarcinogenic agents, carrier proteins, caspases, cell division, dietary supplements, drug evaluation, lung metabolism, metaplasia, animal models, phosphorylation, post translational drug effects.

Lloyd, C.G. and W.G. Lewis (2004). **Two cases of pancreatic neoplasia in British ferrets (*Mustela putorius furo*).** *The Journal of Small Animal Practice* 45(11): 558-562.

**NAL Call Number:** 41.8 J8292

**Abstract:** Two six-year-old male neutered polecat ferrets (*Mustela putorius furo*) were presented for the investigation of acute collapse or periodic weakness and weight loss. While blood biochemistry revealed hypoglycaemia in both cases, diagnosis of an insulin-secreting neoplasia was confirmed by exploratory surgery in one case and supported by the use of an insulin assay in the other. Subsequent histopathological examination showed the former to be a pancreatic islet cell carcinoma and the latter to be a pancreatic islet cell adenoma. While neoplasia of the pancreas commonly affects ferrets in the USA, there appears to be only one previous report from the UK.

**Descriptors:** ferrets, adenoma, islet cell, carcinoma, pancreatic neoplasms, epidemiology, pathology, carcinoma islet cell, epidemiology, pathology, Great Britain, epidemiology, immunohistochemistry, pancreatic neoplasms, epidemiology, pathology.

Mayer, J. (2006). **Update on ferret lymphoma.** In: *Small animal and exotics Proceedings of the North American Veterinary Conference., January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1748-1749.

**Online:** <http://www.tnavc.org>

**Descriptors:** ferrets, update, lymphoma, radiotherapy, treatment, diagnosis.

Mikaelian, I. and M.M. Garner (2002). **Solitary dermal leiomyosarcomas in 12 ferrets.** *Journal of Veterinary Diagnostic Investigation* 14(3): 262-265. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** Twelve 3-6-year-old ferrets (8 males, 3 females, 1 unknown) were presented with single cutaneous nodules. These dermal tumors were characterized histologically by nodular proliferation of neoplastic smooth muscle fibers with marked anisokaryosis and a mitotic rate of >2 mitoses per 10 high-power fields. Neoplastic

cells stained strongly for vimentin in all tumors and for smooth muscle actin and desmin in all but 1 tumor. Histologic and immunohistochemical findings suggested a diagnosis of piloleiomyosarcoma for these tumors. Excision was curative in all animals available for follow-up. However, 3 of 5 animals developed adrenal disease within 7 months after removal of the dermal leiomyosarcoma.

**Descriptors:** ferrets, leiomyosarcoma, immunohistochemistry, leiomyosarcoma pathology, smooth muscle pathology, skin neoplasms pathology, dermal tumors.

Munday, J.S., C.A. Brown, and L.J. Richey (2004). **Suspected metastatic coccygeal chordoma in a ferret (*Mustela putorius furo*)**. *Journal of Veterinary Diagnostic Investigation* 16(5): 454-458. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** A chordoma was removed from the tail base of a 6.5-year-old ferret (*Mustela putorius furo*). A nodule was observed in the area of tumor development when the ferret was purchased at 3 months of age. Although the nodule did not enlarge for 2 years, slow, steady growth of the tumor was observed for 4 years before surgical removal. Eight months after removal of the chordoma, the ferret developed 2 cutaneous masses. One was adjacent to the vulva, close to where the chordoma had been removed from, whereas the other was in the nasofacial region. After 4 months of slow growth, both masses were removed and both were histologically and immunohistochemically consistent with chordoma. Over the next 8 weeks, additional masses developed in the facial, maxillary gingival, and scapular regions. Enlargement of the gingival mass caused dysphagia, and the ferret was euthanized. Although a necropsy was not performed, these additional masses had a clinical appearance and texture that was similar to the 2 previously removed cutaneous chordomas. To the authors' knowledge, this is the first report of a ferret coccygeal chordoma that developed close to the base of the tail. Ferret chordomas have been reported previously to metastasize to the subcutis overlying the tumor. However, this is the first report of a ferret chordoma that metastasized to a location distant to the primary site of neoplasm development. Cell proliferation indices did not predict this metastatic behavior. It is hypothesized that the long clinical period before removal may have predisposed this neoplasm to metastasis. Observations from this case suggest that chordomas in ferrets may have metastatic potential and so should be removed promptly.

**Descriptors:** chordoma, ferrets, spinal neoplasms, surgery, facial neoplasms, sacrococcygeal region, skin neoplasms, spinal neoplasms, vulvar neoplasms.

Munday, J.S., N.L. Stedman, and L.J. Richey (2003). **Histology and immunohistochemistry of seven ferret vaccination-site fibrosarcomas**. *Veterinary Pathology* 40(3): 288-293. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** The anatomical location, histology, and immunohistochemistry of 10 ferret dermal and subcutaneous fibrosarcomas were examined. Seven of the 10 tumors were from locations used for vaccination. All fibrosarcomas contained spindle-shaped cells surrounded by variable quantities of connective tissue stroma. However, vaccination-site fibrosarcomas (VSFs) subjectively contained a higher degree of cellular pleomorphism. Multinucleated cells were present in three of seven VSFs but not in any of the nonvaccination-site fibrosarcomas (NVSFs). Large histiocytic cells, interpreted as macrophages, containing intracytoplasmic basophilic granular material were observed in two VSFs but not in any of the NVSFs. Five VSFs contained peripheral lymphoplasmacytic aggregates. Immunohistochemically, three VSFs stained with anti-smooth muscle actin antibodies and one stained with antibodies against desmin. No expression of muscle cytoskeletal filaments was observed in any NVSF. Filaments interpreted as actin were visible in both the VSFs examined ultrastructurally. One of the VSFs examined ultrastructurally contained intracytoplasmic crystalline material. The preferential development of subcutaneous fibrosarcomas in vaccination sites suggests that, as in cats, vaccination may promote local sarcoma development in ferrets. Additionally, some of the histologic, immunohistochemical, and ultrastructural features of these tumors are similar to those reported for feline vaccine-associated sarcomas. To the authors' knowledge, vaccination has not previously been reported to be oncogenic in any species other than cats.

**Descriptors:** ferrets, fibrosarcoma, soft tissue neoplasms, vaccination adverse effects, fibrosarcoma etiology, pathology, ultrastructure, immunohistochemistry, retrospective studies, etiology.

Nakanishi, M., M. Kuwamura, J. Yamate, D. Fujita, and H. Sasai (2005). **Gastric adenocarcinoma with ossification in a ferret (*Mustela putorius furo*)**. *Journal of Veterinary Medical Science* 67(9): 939-941. ISSN: 0916-7250.

**Abstract:** A 6-year-old female ferret had a firm mass 2 cm in diameter in the pyloric region of the stomach.

Histopathologically, the mass was composed of neoplastic proliferation of well-differentiated epithelial cells, showing tubular or glandular growth patterns. Osseous metaplastic foci were often found in the tumor. Tumor cells showed a positive reaction for immunohistochemistry against bone morphogenetic protein-6, an osteogenic factor. A diagnosis of gastric adenocarcinoma with ossification was made.

**Descriptors:** ferrets, adenocarcinoma, pathology, stomach neoplasms, bone, morphogenetic proteins.

Newman, S.J., P.J. Bergman, B. Williams, T. Scase, and D. Craft (2004). **Characterization of spindle cell component of ferret (*Mustela putorius furo*) adrenal cortical neoplasms - correlation to clinical parameters and prognosis.** *Veterinary and Comparative Oncology* 2(3): 113-124. ISSN: 1476-5810.

**Descriptors:** ferret, adenoal cortical neoplasms, spindle cell component, clinical parameters, prognosis, diagnosis, histopathology, immunohistochemistry.

Patterson, M.M., A.B. Rogers, M.D. Schrenzel, R.P. Marini, and J.G. Fox (2003). **Alopecia attributed to neoplastic ovarian tissue in two ferrets.** *Comparative Medicine* 53(2): 213-217. ISSN: 1532-0820.

**NAL Call Number:** SF77 .C65

**Abstract:** Ferrets with adrenal gland dysfunction have alopecia as their most common clinical sign of disease. Two cases of alopecia in neutered female ferrets are reported that were associated instead with neoplastic tissue found at the site of an ovarian pedicle. Androstenedione and 17-hydroxyprogesterone, but not estradiol, concentrations were high in both ferrets. Following surgical resection of the abnormal tissue in one ferret, the high hormone values decreased quickly and hair regrowth ensued. In both cases, histologic examination revealed features consistent with classical sex cord-stromal (gonadostromal) tumors: prominent spindle cells, along with polyhedral epithelial cells and cells with vacuolated cytoplasm. Although similar cell types have been described in the adrenal glands of ferrets with adrenal-associated endocrinopathy, an ovarian origin for the current neoplasms is considered likely on the basis of their anatomic location; accessory adrenal tissue has only been described close to an adrenal gland or in the cranial perirenal fat of ferrets. Immunohistochemical analysis, using an antibody against Mullerian-inhibiting substance, failed to prove definitively the source of the steroidogenic cells.

**Descriptors:** ferrets, alopecia, adrenal gland diseases, ovarian cancer, estradiol, progesterone, androstenedione, immunohistochemistry, excision of the ovaries.

Peterson, R.A., M. Kiupel, M. Bielinska, S. Kiiveri, M. Heikinheimo, C.C. Capen, and D.B. Wilson (2004).

**Transcription factor GATA-4 is a marker of anaplasia in adrenocortical neoplasms of the domestic ferret (*Mustela putorius furo*).** *Veterinary Pathology* 41(4): 446-449. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Adrenocortical neoplasms are a common cause of morbidity in neutered ferrets. Recently we showed that gonadectomized DBA/2J mice develop adrenocortical tumors that express transcription factor GATA-4. Therefore, we screened archival specimens of adrenocortical neoplasms from neutered ferrets to determine whether GATA-4 could be used as a tumor marker in this species. Nuclear immunoreactivity for GATA-4 was evident in 19/22 (86%) of ferret adrenocortical carcinomas and was prominent in areas exhibiting myxoid differentiation. Normal adrenocortical cells lacked GATA-4 expression. Two other markers of adrenocortical tumors in gonadectomized mice, inhibin-alpha and luteinizing hormone receptor, were coexpressed with GATA-4 in some of the ferret tumors. No GATA-4 expression was observed in three cases of nodular hyperplasia, but patches of anaplastic cells expressing GATA-4 were evident in 7/14 (50%) of tumors classified as adenomas. We conclude that GATA-4 can function as a marker of anaplasia in ferret adrenocortical tumors.

**Descriptors:** ferrets, adrenal cortex neoplasms, adrenocortical carcinoma, DNA binding, proteins metabolism, transcription factors, tumor markers, biological metabolism.

Peterson, R.A., M. Kiupel, and C.C. Capen (2003). **Adrenal cortical carcinomas with myxoid differentiation in the domestic ferret (*Mustela putorius furo*).** *Veterinary Pathology* 40(2): 136-142. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** A total of 15 adrenocortical carcinomas with myxoid differentiation from 15 ferrets were evaluated in this retrospective study. Six of these ferrets (40%) either were euthanatized or died due to invasive and/or metastatic disease. The myxoid component was a variable part (between 5% and 95%) of the adrenal cortical neoplasm and consisted of sheets and cords of small, polygonal neoplastic cells that formed lumenlike spaces.

Such spaces contained a variable amount of alcian blue (pH 2.5)-positive mucinous product (i.e., acidic mucopolysaccharides). Neoplastic cells were negative for the argentaffin reaction, but immunohistochemically they were strongly positive for vimentin and alpha-inhibin and lightly positive for synaptophysin. Proliferating cell nuclear antigen (PCNA)-labeling indices (LI) of adrenal cortical neoplastic cells within the myxoid component of the neoplasm were significantly elevated ( $P < 0.05$ ) compared with those of typical neoplastic adrenal cortical cells or the adjacent nonneoplastic zona reticularis. Ultrastructurally, cells in the myxoid component exhibited a typical adrenocortical phenotype characterized by cytoplasmic lipid vacuoles, prominent rough and smooth endoplasmic reticulum, and zonula adherens. This lesion was interpreted as an adrenal cortical carcinoma with myxoid differentiation and appeared to be highly malignant based on PCNA LI, rate of invasion into adjacent tissue, and metastasis (6/15). This report is the first description of this histologic variant in the ferret, which morphologically resembled the rare myxoid variant of adrenocortical carcinoma described in humans.

**Descriptors:** ferrets, adrenal cortex neoplasms, adrenocortical carcinoma, myxoma, biopsy, immunohistochemistry, electron microscopy, proliferating cell nuclear antigen, retrospective studies, synaptophysin, vimentin.

Peterson, R.A. II, M. Kiupel, M. Bielinska, S. Kiiveri, M. Heikinheimo, C.C. Capen, and D.B. Wilson (2004).

**Transcription factor GATA-4 is a marker of anaplasia in adrenocortical neoplasms of the domestic ferret (*Mustela putorius furo*).** *Veterinary Pathology* 41(4): 446-449. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Descriptors:** ferret, adenocortical neoplasms, transcription factor GATA-4, disease marker, anaplasia.

Pilny, A.A. and S. Chen (2004). **Ferret insulinoma: Diagnosis and treatment.** *Compendium on Continuing Education for the Practicing Veterinarian* 26(9): 722-728. ISSN: 0193-1903.

**NAL Call Number:** SF601.C66

**Descriptors:** ferret, insulinoma, diagnosis, treatment, neoplasia.

Sakai, H., M. Maruyama, A. Hirata, K. Yonemaru, T. Yanai, and T. Masegi (2004). **Rhabdomyosarcoma in a ferret (*Mustela putorius furo*).** *Journal of Veterinary Medical Science* 66(1): 95-96. ISSN: 0916-7250.

**Abstract:** A 5-year-old spayed male ferret showed a subcutaneous mass in the right lateral thoracic wall. Microscopic examination revealed that the neoplasm had proliferated in the subcutis with infiltration into the surrounding tissues. A packed bundle of large polymorphic neoplastic cells, containing abundant eosinophilic cytoplasm and a round to ovoid, occasionally bizarre nucleus, were arranged interwoven. The neoplasm had metastasized to the right axillary lymph node. The neoplastic cells were intensively positive for vimentin, desmin and myoglobin. Skeletal muscle type creatine phosphokinase-positive granules were detected in the cytoplasm. Ultrastructurally, various amounts of disorganized myofibrils with focal density resembling the Z-band were shown in the cytoplasm of the neoplastic cells. The neoplasia was diagnosed as rhabdomyosarcoma.

**Descriptors:** ferrets, rhabdomyosarcoma, thoracic neoplasms, diagnosis, differential, neoplasm invasiveness, orchiectomy, pathology, ultrastructure.

Saunders, G.K. and B.V. Thomsen (2006). **Lymphoma and *Mycobacterium avium* infection in a ferret (*Mustela putorius furo*).** *Journal of Veterinary Diagnostic Investigation* 18(5): 513-515. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** A 6-year-old, neutered male ferret presented with weight loss. Radiography revealed an enlarged liver and other abdominal masses. The ferret was euthanized, and at necropsy, the stomach wall was thickened, mesenteric lymph nodes were enlarged, and the liver contained multifocal tan nodules. Histopathology confirmed lymphoma and granulomatous inflammation in all affected organs. Acid-fast bacilli were present in the lesions and were confirmed to be *Mycobacterium avium* by PCR.

**Descriptors:** ferrets, lymphoma, *Mycobacterium avium*, tuberculosis, fatal outcome, histocytochemistry, lymphoma.

Schoemaker, N.J., M.H. Hage van der, G. Flik, J.T. Lumeij, and A. Rijnberk (2004). **Morphology of the pituitary gland in ferrets (*Mustela putorius furo*) with hyperadrenocorticism.** *Journal of Comparative Pathology* 130(4): 255-265. ISSN: 0021-9975.

**NAL Call Number:** 41.8 J82

**Descriptors:** ferrets, diseases, adrenal glands, histopathology, neoplasms, physiopathology, pituitary, morphology.

Schoemaker, N.J., M.H. van der Hage, G. Flik, J.T. Lumeij, and A. Rijnberk (2004). **Morphology of the pituitary gland in ferrets (*Mustela putorius furo*) with hyperadrenocorticism.** *Journal of Comparative Pathology* 130(4): 255-265. ISSN: 0021-9975.

**NAL Call Number:** 41.8 J82

**Abstract:** Pituitary tumours are the cause of hyperadrenocorticism in a variety of species, but the role of the pituitary gland in hyperadrenocorticism in ferrets is not known. In this species, the disease is mediated by the action of excess gonadotrophins on the adrenal cortex and is characterized by an excessive secretion of sex steroids. In this study, the pituitary gland of four healthy control ferrets, intact or neutered, and 10 neutered ferrets with hyperadrenocorticism was examined histologically following immunohistochemical labelling for adrenocorticotrophic hormone, alpha-melanocyte-stimulating hormone, growth hormone, thyroid-stimulating hormone, luteinizing hormone, follicle-stimulating hormone, and prolactin. Immunohistochemistry revealed that somatotrophs, thyrotrophs and lactotrophs were the most abundant cell types of the pars distalis of the pituitary gland in the healthy ferrets. The distribution of corticotrophs was similar to that in the dog and man. In ferrets, as in dogs, the melanotrophic cell was almost the only cell type of the pars intermedia. Gonadotrophs were found in the pars distalis of neutered, but not intact ferrets. All the ferrets with hyperadrenocorticism had unilateral or bilateral alterations of the adrenal gland. In addition, in the pituitary gland of two of these ferrets a tumour was detected. These tumours were not immunolabelled by antibodies against any of the pituitary hormones, and had characteristics of the clinically non-functional gonadotroph tumours seen in man. In some of the other ferrets low pituitary immunoreactivity for gonadotrophic hormones was detected, which may have been due to the feedback of autonomous steroid secretion by the neoplastic transformation of the adrenal cortex. It is concluded that initially high concentrations of gonadotrophins resulting from castration may initiate hyperactivity of the adrenal cortex. The low incidence of pituitary tumours and the low density of gonadotrophin-positive cells in non-affected pituitary tissue in this study suggest that persistent hyperadrenocorticism is not dependent on persistent gonadotrophic stimulation.

**Descriptors:** ferrets, adrenocortical hyperfunction, pituitary gland, adenoma, adrenal glands, castration, pituitary neoplasms.

Stauber, E. and T.J. Baldwin (2005). **Ameloblastoma in a ferret.** *Exotic DVM* 6(6): 9. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, ameloblastoma, clinical aspects, diagnosis, histopathology, tumors, surgery, therapy.

Tunev, S.S. and M.G. Wells (2002). **Cutaneous melanoma in a ferret (*Mustela putorius furo*).** *Veterinary Pathology* 39(1): 141-143. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** A 4-year-old spayed female ferret (*Mustela putorius furo*) was clinically evaluated for a slightly raised subcutaneous mass in the dorsal lumbar area. The mass was surgically excised and submitted for histopathologic evaluation. Histologically, the mass was composed of closely packeted large, atypical, polygonal to spindle-shaped cells arranged in sheets and short bundles. A few cells contained variable amounts of granular, brown to black intracytoplasmic pigment. Warthin-Starry and Fontana-Masson silver stains demonstrated variable numbers of fine black intracytoplasmic granules in most cells. The atypical cells stained positively for vimentin and S100 protein and negatively for cytokeratin and Melan A. Ultrastructurally, the neoplastic cells contained intracytoplasmic melanosomes in different stages of development. Compound melanosomes were not identified. To our knowledge, this report documents the first case of a spontaneous cutaneous melanoma in the ferret.

**Descriptors:** ferrets, melanoma, skin neoplasms, melanoma, ultrastructure, ovariectomy, skin pathology.

van Zeeland, Y.R., S.J. Hernandez Divers, M.W. Blasier, G. Vila Garcia, D. Delong, and N.L. Stedman (2006). **Carpal myxosarcoma and forelimb amputation in a ferret (*Mustela putorius furo*).** *Veterinary Record* 159(23): 782-785. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Descriptors:** ferret, carpal myxosarcoma, forelimb amputation.

Whittington, J.K., J.A. Emerson, T.M. Satkus, G. Tyagi, A. Barger, and M.E. Pinkerton (2006). **Exocrine pancreatic carcinoma and carcinomatosis with abdominal effusion containing mast cells in a ferret (*Mustela putorius furo*)**. *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 643-650. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** This case describes the clinical presentation and findings of exocrine pancreatic carcinoma in a 9-year-old female sprayed ferret (*Mustela putorius furo*). Transcoelomic metastasis and hemorrhagic abdominal effusion were secondary to the neoplasm. The finding of mast cells in abdominal effusion, with a leukocyte component composed primarily of lymphocytes and lesser numbers of neutrophils and macrophages, is an atypical finding, never before reported in ferrets.

**Descriptors:** ferret, carcinoma, mast cells, abdominal effusion, metastasis.

Williams, B.H. (2002). **Squamous cell carcinoma arising from the anal sac in a ferret**. *Exotic DVM* 4(2): 7. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferret, anal glands, squamous cell carcinoma, clinical aspects, diagnosis, tumors.

Wills, T.B., A.A. Bohn, N.P. Finch, S.P. Harris, and P. Caplazi (2005). **Thyroid follicular adenocarcinoma in a ferret**. *Veterinary Clinical Pathology* 34(4): 405-408. ISSN: 0275-6382.

**NAL Call Number:** SF601.A54

**Abstract:** A 5-year-old male castrated ferret was presented to the Washington State University College of Veterinary Medicine for evaluation of progressive hair loss and a large, rapidly growing ventral neck mass. The patient had been diagnosed previously with an insulinoma, which was managed medically. Fine-needle aspirates of the neck mass were performed. The cytologic results were most consistent with epithelial neoplasia, likely a carcinoma; thyroid origin was considered likely based on tumor location and cell morphology. The tumor grew rapidly, and the owners elected euthanasia 1 week after examination. At necropsy, a circumscribed, ovoid mass disrupted the right cervical musculature next to the right lobe of the thyroid gland. Histopathologic evaluation revealed an infiltrative mass consisting of cuboidal cells arranged in solid sheets and irregular follicles enclosing colloid. The cells were large, with prominent nucleoli, and had a high mitotic rate. The histopathologic diagnosis was consistent with thyroid follicular adenocarcinoma. Immunochemical findings confirmed thyroglobulin production by neoplastic cells, but to a lesser extent than in normal ferret thyroid tissue. To our knowledge, this is the first case of thyroid follicular adenocarcinoma to be reported in a ferret, with only 1 other case of thyroid carcinoma, a C-cell carcinoma, described previously.

**Descriptors:** ferrets, follicular adenocarcinoma, thyroid neoplasms, immunohistochemistry, thyroid gland, neoplasms, case study.

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## Information Resources on the Care and Welfare of Ferrets

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### Neurological/Nervous System

Gierdalski, M., S.P. Sardi, G. Corfas, and S.L. Juliano (2005). **Endogenous neuregulin restores radial glia in a (ferret) model of cortical dysplasia.** *Journal of Neuroscience* 25(37): 8498-8504. ISSN: 1529-2401.

**Abstract:** Radial glia are integral components of the developing neocortex. During corticogenesis, they form an important scaffold for neurons migrating into the cortical plate. Recent attention has focused on neuregulin (NRG1), acting through erbB receptors, in maintaining their morphology. We developed a model of developmental radial glial disruption by delivering an antimetabolic [methylazoxy methanol (MAM)] to pregnant ferrets on embryonic day 24 (E24). We previously found that normal ferret cortex contains a soluble factor capable of realigning the disorganized radial glia back toward their normal morphology. Characterization of the reorganizing activity in normal cortex demonstrated that the probable factor mediating these responses was a 30-50 kDa protein. To test whether this endogenous soluble factor was NRG1, we used organotypic cultures of E24 MAM-treated ferret neocortex supplemented with the endogenous factor obtained from normal cortical implants, exogenous NRG1beta, antibodies that either blocked or stimulated erbB receptors, or a soluble erbB subtype that binds to available NRG1. We report that exogenous NRG1 or antibodies that stimulate erbB receptors dramatically improve the morphology of disrupted radial glia, whereas blockade of NRG1-erbB signaling prevents the radial glial repair. Our results suggest that NRG1 is an endogenous factor in ferret neocortex capable of repairing damaged radial glia and that it acts via one or more erbB receptors.

**Descriptors:** ferrets, cerebral cortex, neuregulins, neuroglia, animal models, newborn disease models, methylazoxymethanol acetate, prenatal exposure, corticogenesis.

Hoffmann, K.P., N. Garipis, and C. Distler (2004). **Optokinetic deficits in albino ferrets (*Mustela putorius furo*): A behavioral and electrophysiological study.** *Journal of Neuroscience* 24(16): 4061-4069. ISSN: 1529-2401.

**Abstract:** We compared the horizontal optokinetic reaction (OKR) and response properties of retinal slip neurons in the nucleus of the optic tract and dorsal terminal nucleus (NOT-DTN) of albino and wild-type ferrets (*Mustela putorius furo*). In contrast to pigmented ferrets, we were unable to observe OKR in albino ferrets during binocular and monocular viewing using random dot full field stimulation and electro-oculography (EOG). Observations during early postnatal life indicate that regular OKR is present in pigmented pups 3 d after eye opening but is absent at any stage during development in albino ferrets. Unilateral muscimol injections to inactivate all neurons in the NOT-DTN containing GABA(A) and GABA(C) receptors caused spontaneous horizontal nystagmus with slow phases away from the injected hemisphere in albino as well as in pigmented animals. Retinal slip neurons in the NOT-DTN of albino ferrets identified by antidromic activation from the inferior olive and orthodromic activation from the optic chiasm were well responding to intermittent bright light stimuli, but many showed a profound reduction of responsiveness to moving stimuli. The movement-sensitive neurons exhibited no clear direction selectivity for ipsiversive stimulus movement, a characteristic property of these neurons in pigmented ferrets and other mammals. Thus, the defect rendering albino ferrets optokinetically nonresponsive is located in the visual pathway subserving the OKR, namely in or before the NOT-DTN, and not in oculomotor centers.

**Descriptors:** ferrets, albinism, physiopathology, eye movements, motion perception, visual pathways, behavior, electrooculography, electrophysiology, nystagmus, olivary nucleus, optic chiasm, photic stimulation.

Kawasaki, H., J.C. Crowley, F.J. Livesey, and L.C. Katz (2004). **Molecular organization of the ferret visual thalamus.** *Journal of Neuroscience* 24(44): 9962-9970. ISSN: 1529-2401.

**Abstract:** The visual system encodes and deciphers information using parallel, anatomically segregated, processing streams. To reveal patterns of gene expression in the visual thalamus correlated with physiological processing streams, we designed a custom ferret cDNA microarray. By isolating specific subregions and layers of the thalamus, we identified a set of transcription factors, including *Zic2*, *Islet1*, and *Six3*, the unique distribution profiles of which differentiated the lateral geniculate nucleus (LGN) from the associated perigeniculate nucleus. Within the LGN, odd homeobox1 differentiated the A layers, which contain X cells and Y cells, from the C layers. One neuron-specific protein, Purkinje cell protein 4 (PCP4), was strongly expressed in Y cells in the ferret LGN and in the magnocellular layers of the primate LGN. In the ferret LGN, PCP4 expression began as early as postnatal day 7 (P7), suggesting that Y cells are already specified by P7. These results reveal a rich molecular repertoire that correlates with functional divisions of the LGN.

**Descriptors:** ferrets, geniculate bodies, neurons, visual pathways, ferret growth and development, gene expression profiling, immunohistochemistry, *Macaca fascicularis*, nerve tissue protein biosynthesis, visual pathways.

Odekunle, A. and T.I. Chinnah (2003). **Brainstem origin of duodenal vagal preganglionic parasympathetic neurons. A WGA-HRP study in the ferret (*Mustela Putorius Furo*), a human model.** *West Indian Medical Journal* 52(4): 267-272. ISSN: 0043-3144.

**Abstract:** The projections of vagal brainstem neurons to the duodenal segment of the gastrointestinal tract were studied in the ferret using the WGA-HRP neurohistochemical technique. Fourteen adult ferrets with weights ranging from 800 gm to 1500 gm were used for the study. The muscular wall of the duodenum of six ferrets was injected with 0.1 ml of 5% WGA-HRP in 0.5 M sodium chloride. The eight remaining ferrets were used as controls. Two of these had injections of 0.1 ml normal saline into the muscular wall of the duodenum. The second set of two ferrets was injected with 0.1 ml of 5% WGA-HRP in buffer after bilateral truncal vagotomy. The third set of two ferrets received intraperitoneal injection of 0.1 ml of 5% WGA-HRP while, in the last set, the tracer was injected into the hepatic portal vein. Following the injections, the ferrets were allowed to survive for 48-72 hours after which each ferret was perfused transcardially first with normal saline followed by a fixative containing 1% paraformaldehyde and 1.25% glutaraldehyde in 0.1 M phosphate buffer, pH 7.4 at room temperature and finally with 10% buffered sucrose at 4 degrees C. Transverse serial frozen sections of the brainstem were then taken and processed for WGA-HRP neurohistochemistry and were analyzed under light and dark-field illuminations. The analyses of the sections taken from the six ferrets injected with WGA-HRP revealed neurons labelled with the tracer in the dorsal motor nucleus of the vagus nerve (DMNV). Sections taken from the control ferrets did not reveal any WGA-HRP labelled neurons in the brainstem.

**Descriptors:** ferrets, preganglionic autonomic fibers, duodenum innervation, molecular probes, parasympathetic nervous system, vagus nerve, animal models, neural pathways.

Philipp, R., C. Distler, and K.P. Hoffmann (2006). **A motion-sensitive area in ferret extrastriate visual cortex: An analysis in pigmented and albino animals.** *Cerebral Cortex* 16(6): 779-790. ISSN: 1047-3211.

**Abstract:** In search of the neuronal substrate for motion analysis in the ferret (*Mustela putorius furo*), we extracellularly recorded from extrastriate visual cortex in five pigmented and two albino ferrets under general anaesthesia and paralysis. Visual stimulation consisted of large area random dot patterns moving either on a circular path in the frontoparallel plane or expanding and contracting radially. Strongly direction-selective neurons were recorded in a circumscribed area in and just posterior to the suprasylvian sulcus, thus named by us the posterior suprasylvian area (area PSS). Altogether, we recorded 210 (90%) and 95 (72%) PSS neurons in pigmented and albino ferrets, respectively, that were direction selective. In these neurons responses during random dot pattern stimulation in the preferred direction were at least twice as strong than stimulation in the non-preferred direction. Response strength in preferred direction and tuning sharpness of PSS neurons in albinos were significantly reduced when compared to pigmented animals (median values: 34.1 versus 14.8 spikes/s and 142 versus 165 degrees for pigmented and albino ferrets, respectively). Inter-spike-intervals during visual stimulation were significantly shorter in pigmented (median 9 ms) than in albino PSS neurons (median 14 ms). Our data indicate that area PSS may play a crucial role in motion perception in the ferret.

**Descriptors:** ferrets, albinism, ocular physiopathology, motion perception, nerve net, visual cortex, evoked

potentials, photic stimulation, pigmentation.

Platt, S.R., P.M. Dennis, and L.J. McSherry (2004). **Composition of cerebrospinal fluid in clinically normal adult ferrets.** *American Journal of Veterinary Research*: 758-760. ISSN: 0002-9645.

**NAL Call Number:** 41.8 Am3A

**Abstract:** Objective--To determine the protein and cellular composition of CSF in healthy adult ferrets. Animals--42 clinically normal adult ferrets. Procedure--CSF samples were collected from the cerebellomedullary cistern of anesthetized ferrets by use of disposable 25-gauge, 1.6-cm-long hypodermic needles. Samples were processed within 20 minutes after collection. The number of WBCs and RBCs per microliter of CSF was counted by use of a hemacytometer. The total protein concentration was determined by use of an automated chemistry analyzer. Results--Total WBC counts (range, 0 to 8 cells/mL; mean, 1.59 cells/mL) in CSF of ferrets were similar to reference range values obtained for CSF from other species. Twenty-seven CSF samples had < 100 RBCs/mL (mean, 20.3 RBCs/mL). A small but significant effect of blood contamination on WBC counts was found between the 27 CSF samples with < 100 RBCs/mL and the remaining samples. Protein concentrations in CSF of ferrets (range, 28.0 to 68.0 mg/dL; mean, 31.4 mg/dL) were higher than has been reported for the CSF of dogs and cats. A significant effect of blood contamination on the CSF protein concentration was not found. Conclusion and Clinical Relevance--We have established reference range values for WBC counts and protein concentrations in CSF from healthy adult ferrets that may be useful in the clinical investigation of CNS disease. Results of our study indicate that the WBC count is significantly affected by blood contamination of the CSF sample. Reprinted by permission of the publisher.

**Descriptors:** normal ferrets, adult, cerebral spinal fluid, anesthesia, white blood cell counts.

Shintani, T., A.R. Anker, I. Billig, J.P. Card, and B.J. Yates (2003). **Transneuronal tracing of neural pathways influencing both diaphragm and genioglossal muscle activity in the ferret.** *Society for Neuroscience Abstract Viewer and Itinerary Planner 2003*: Abstract No. 609.1.

**Descriptors:** ferret, neural pathways, transneuronal tracing, diaphragm, genioglossal muscle activity, upper airway, respiratory pump muscles.

**Notes:** 33rd Annual Meeting of the Society of Neuroscience, New Orleans, LA, USA; November 08-12, 2003.

Shintani, T., R.L. Mori, and B.J. Yates (2003). **Locations of neurons with respiratory-related activity in the ferret brainstem.** *Brain Research* 974(1-2): 236-242. ISSN: 0006-8993.

**Descriptors:** ferret, brain stem, respiratory related activity, coughing, emesis, location, quiet breathing, motoneurons.

White, L.E. and D. Fitzpatrick (2003). **Dark - rearing prevents the development of direction selectivity in ferret visual cortex.** *Society for Neuroscience Abstract Viewer and Itinerary Planner 2003*: Abstract No. 567.12.

**Descriptors:** ferrets, dark rearing, visual cortex, development, direction selectivity, prevents, visual experience, meeting abstract.

**Notes:** 33rd Annual Meeting of the Society of Neuroscience, New Orleans, LA, USA; November 08-12, 2003.

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### Parasites

- Abe, N., C. Read, R.C.A. Thompson, and M. Iseki (2005). **Zoonotic genotype of *Giardia intestinalis* detected in a ferret.** *The Journal of Parasitology* 91(1): 179-182. ISSN: 0022-3395.  
**NAL Call Number:** 448.8 J824  
**Descriptors:** ferrets, *Giardia lamblia*, genotype, ribosomal RNA, glutamate dehydrogenase, structural genes, nucleotide sequences, sequence homology, phylogeny, giardiasis, zoonoses, beta giardin gene, glutamate dehydrogenase gene.
- Chiaravaccini, L., C. D' Agostino, and S. Perrucci (2003). **Aspetti parassitologici e clinici della coccidiosi e dell'otocariasi del furetto (*Mustela putorius furo*).** [Parasitological and clinical aspects of coccidiosis and auricular mange of the ferret (*Mustela putorius furo*)]. *Veterinaria* 17(3): 73-76. ISSN: 0391-3151.  
**Descriptors:** ferret, coccidiosis, auricular mange, parasites, clinical aspects, examination, diagnosis, *Otodectes cynotis*, polecats, *Eimeria furonis*, *Isospora laidlawii*.  
**Language of Text:** Italian; Summary in English.
- Cottrell, D.K. (2004). **Use of moxidectin (ProHeartReg. 6\*) as a heartworm adulticide in 4 ferrets.** *Exotic DVM* 6(5): 9-12. ISSN: 1521-1363.  
**NAL Call Number:** SF981 .E96  
**Descriptors:** ferrets, heartworms, clinical aspects, diagnosis, drug therapy, *Dirofilaria immitis*, moxidectin.
- Larsen, K. S, H. Siggurdsson, and N. Mencke (2005). **Efficacy of imidacloprid, imidacloprid/permethrin and phoxim for flea control in the Mustelidae (ferrets, mink).** *Parasitology Research* 97(Suppl 1): S107-S112. ISSN: 0932-0113.  
**Abstract:** Farmed mink (*Mustela vison*), a close relative of the domestic ferret (*Mustela putorius furo*), naturally infested with the squirrel flea (*Ceratophyllus sciurorum*) were included in a study to investigate three compounds for flea control. The test products were imidacloprid in a 10% (w/v) solution, an imidacloprid 10% (w/v)/permethrin 50% (w/v) solution, and phoxim; all three are well-known compounds for the control of different ectoparasites in a wide range of animals. Two groups of mink received 0.1 ml per animal of the imidacloprid or the imidacloprid/permethrin combination at days 0 and 28, respectively. Two groups of mink were sprayed with 25 ml of a 0.1% phoxim solution at day 0 and either 1x25 ml or 2x25 ml, respectively, of a 0.05% phoxim solution at day 28. One group of mink served as an untreated control. At assessment on day 56 the efficacy was 91.9% in the imidacloprid group, 89.3% in the imidacloprid/permethrin group, 92.2% in the phoxim 1x25-ml group and 99.3% in the phoxim 2x25 ml group, respectively. In the untreated control group an average of 757 fleas per mink nesting material was recorded.  
**Descriptors:** mink, ferret, squirrel flea, flea control, ectoparasites, imidacloprid, permethrin, phoxim, efficacy.
- Miller, D.S., R.P. Eagle, S. Zabel, R. Rosychuk, and T.W. Campbell (2006). **Efficacy and safety of selamectin in the treatment of *Otodectes cynotis* infestation in domestic ferrets.** *Veterinary Record* 159(22): 748. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Descriptors:** ferrets, Otodectes, infestation, treatment, efficacy, safety, selamectin.

Webster, P. and C.M. Kapel (2005). **Studies on vertical transmission of *Trichinella* spp. in experimentally infected ferrets (*Mustela putorius furo*), foxes (*Vulpes vulpes*), pigs, guinea pigs and mice.** *Veterinary Parasitology* 130(3-4): 255-262. ISSN: 0304-4017.

**NAL Call Number:** SF810.V4

**Abstract:** Vertical transmission of *Trichinella spiralis* was evaluated in ferrets (n=21), foxes (n=11), pigs (n=12), guinea pigs (n=16), and mice (n=41). The placental barrier to be crossed by migratory *Trichinella* larvae varies structurally in different animal species. Ferrets and foxes have an endotheliochorial placenta structure, guinea pigs and mice a haemochorial, and pigs an epitheliochorial placenta. The non-encapsulating *Trichinella pseudospiralis* larvae have an extended muscle migration prior to entering a muscle cell. To evaluate if *T. pseudospiralis* was more likely to be transmitted to offspring, an additional group of foxes (n=11) infected with *T. pseudospiralis* was included. Two different dose levels were used for ferrets, pigs, guinea pigs, and mice. In pigs and guinea pigs, infection was given at different times of the gestation period. Vertical transmission, measured as recovery of muscle larvae in the offspring, was demonstrated in both ferrets groups, in all four guinea pig groups, and in the high dose mouse group, but not in any fox or pig groups.

**Descriptors:** ferrets, vertical disease transmission, trichinosis, foxes, guinea pigs, mice, species specificity, swine parasitology, trichinosis transmission.

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### Reproductive

- Angella, P.A., K.A. Margit, J.A. Csaba, and H. Gyula (2004). **Reproduction, genital malfunctions and endocrine disorders of domestic ferrets (*Mustela putorius furo*). 3. Options and limitations in suppression of ovarian activity.** *Magyar Allatorvosok Lapja* 126(7): 419-423. ISSN: 0025-004X.  
**Descriptors:** *Mustela putorius furo*, domestic ferrets, genital malfunctions, reproduction, endocrine disorders, spaying, ovarian activity, literature review.  
**Language of Text:** Hungarian.
- Angella, P.R.A., K.A. Margit, and H. Gyula (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei -irodalmi attekintes 4. Endokrin eredetu bokelvaltozasok, hormonalis megbetegedések. [Reproduction, genital malfunctions and endocrine disorders of domestic ferrets (*Mustela putorius furo*): Literature review. 4. Endocrine skin lesions, hormonal diseases].** *Magyar Allatorvosok Lapja* 126(9): 553-560. ISSN: 0025-004X.  
**Descriptors:** endocrine system, tumor biology, endocrine disease, pathology, metabolic disease, adrenal, metabolic disease, epidemiology, neoplastic disease.  
**Language of Text:** Hungarian.
- Castillo, a.B., L.N. Metz, and R.B. Martin (2003). **The effects of ovariectomy on intracortical remodeling in the female ferret (*Mustela furo*): A pilot study.** *Journal of Musculoskeletal & Neuronal Interactions* 3(4): 418-420. ISSN: 1108-7161.  
**Descriptors:** female ferret, ovariectomy, intracortical remodeling, meeting, pilot study, endocrine system.  
**Notes:** Thirty-third International Sun Valley Hard Tissue Workshop, Sun Valley, ID, USA; August 03-07, 2003.
- Howard, J., P. Marinari, and D. Wildt (2002). **Integration of assisted reproductive technology in the recovery of the black-footed ferret (*Mustela nigripes*).** *American Zoo and Aquarium Association Annual Conference Proceedings 2002*: 55-60.  
**Descriptors:** *Mustela nigripes*, wildlife conservation, assistive reproductive technology, reintroduction programs, black-footed ferrets.
- Howard, J., P.E. Marinari, and D.E. Wildt (2003). **Black-footed ferret: Model for assisted reproductive technologies contributing to in situ conservation.** *Conservation Biology Series* 8: 249-266.  
**Descriptors:** *Mustela nigripes*, black footed ferrets, breeding and reintroduction program, USA, reproductive technology, in situ conservation.
- Kelliher, K.R. and M.J. Baum (2002). **Effect of sex steroids and coital experience on ferrets' preference for the smell, sight and sound of conspecifics.** *Physiology & Behavior* 76(1): 1-7. ISSN: 0031-9384.  
**Descriptors:** ferrets, sex steroids, coital experience, smell, sight, behavior, sound.
- Li, Z., Q. Jiang, M. Rezaei Sabet, Y. Zhang, T.C. Ritchie, and J.F. Engelhardt (2002). **Conditions for in vitro**

**maturation and artificial activation of ferret oocytes.** *Biology of Reproduction* 66(5): 1380-1386. ISSN: 0006-3363.

**Abstract:** The ferret represents an attractive species for animal modeling of lung diseases because of the similarity between ferret and human lung biology and its relatively small size and short gestation time. In an effort to establish experimental protocols necessary for cloning ferrets, optimized conditions for in vitro maturation and artificial activation of ferret oocytes were examined. Cumulus-oocyte complexes were harvested from ovaries of superovulated ferrets, and in vitro maturation was evaluated in three different culture media: medium 1 (TCM-199 + 10% FBS), medium 2 (TCM-199 + 10% FBS with eCG [10 IU/ml] and hCG [5 IU/ml]), or medium 3 (TCM-199 + 10% FBS with eCG, hCG, and 17beta-estradiol [2 microg/ml]). After 24 h of maturation in vitro, the maturation rate of oocytes cultured in medium 2 (70%, n = 79) was significantly greater ( $P < 0.01$ ) than those of oocytes cultured in the other two media (27%-36%, n = 67-73). At 48 h, similar maturation rates (56%-69%, n = 76-87) were observed for all three types of media. For activation experiments, oocytes cultured in medium 2 were stimulated with electrical and chemical stimuli either individually or in combination. Treatment with cycloheximide and 6-dimethylaminopurine (6-DMAP) following electrical stimulation resulted in 43% (n = 58) of the oocytes developing to the blastocyst stage. Such an activation rate represented a significant improvement over those obtainable under other tested conditions, including individual treatment with electrical pulses (10%, n = 41), cycloheximide (3%, n = 58), or 6-DMAP (5%, n = 59). Blastocysts derived from in vitro activation appeared to be normal morphologically and were composed of an appropriate number of both inner cell mass (mean +/- SEM, 10.3 +/- 1.1; n = 11) and trophectoderm (60.8 +/- 2.9, n = 11) cells. These results have begun to elucidate parameters important for animal modeling and cloning with ferrets.

**Descriptors:** ferrets, oocytes, animal model, lung diseases, cycloheximide, electric stimulation, embryonic and fetal development, fertilization in vitro, parthenogenesis, protein synthesis inhibitors, superovulation, ferret lung, human lung, cloning.

Li, Z., X. Sun, J. Chen, G.H. Leno, and J.F. Engelhardt (2006). **Factors affecting the efficiency of embryo transfer in the domestic ferret (*Mustela putorius furo*).** *Theriogenology* 66(2): 183-190. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Abstract:** Embryo transfer (ET) to recipient females is a foundational strategy for a number of assisted reproductive technologies, including cloning by somatic cell nuclear transfer. In an attempt to develop efficient ET in domestic ferrets, factors affecting development of transferred embryo were investigated. Unilateral and bilateral transfer of zygotes or blastocysts in the oviduct or uterus was evaluated in recipient nulliparous or primiparous females. Developing fetuses were collected from recipient animals 21 days post-copulation and examined. The percentage of fetal formation was different ( $P < 0.05$ ) for unilateral and bilateral transfer of zygotes (71%) in nulliparous females with bilateral transfer (56%) in primiparous recipients. The percentage (90%) of fetal formation in nulliparous recipients following unilateral transfer of blastocysts was higher ( $P < 0.05$ ) than that observed in primiparous recipients with bilateral ET (73%). Notably, the percentage of fetal formation was higher ( $P < 0.05$ ) when blastocysts were transferred as compared to zygotes (90% versus 71%). Transuterine migration of embryos occurred following all unilateral transfers and also in approximately 50% of bilateral transfers with different number of embryos in each uterine horn. These data will help to facilitate the development of assisted reproductive strategies in the ferret and could lead to the use of this species for modeling human disease and for conservation of the endangered Mustelidae species such as black-footed ferret and European mink.

**Descriptors:** ferret, embryo transfer, factors, efficiency, reproductive technologies, animal model.

Li, Z., X. Sun, J. Chen, X. Liu, S.M. Wisely, Q. Zhou, J.P. Renard, G.H. Leno, and J.F. Engelhardt (2006). **Cloned ferrets produced by somatic cell nuclear transfer.** *Developmental Biology* 293(2): 439-448. ISSN: 0012-1606.

**NAL Call Number:** 442.8 D49

**Abstract:** Somatic cell nuclear transfer (SCNT) offers great potential for developing better animal models of human disease. The domestic ferret (*Mustela putorius furo*) is an ideal animal model for influenza infections and potentially other human respiratory diseases such as cystic fibrosis, where mouse models have failed to reproduce the human disease phenotype. Here, we report the successful production of live cloned, reproductively competent, ferrets using species-specific SCNT methodologies. Critical to developing a

successful SCNT protocol for the ferret was the finding that hormonal treatment, normally used for superovulation, adversely affected the developmental potential of recipient oocytes. The onset of Oct4 expression was delayed and incomplete in parthenogenetically activated oocytes collected from hormone-treated females relative to oocytes collected from females naturally mated with vasectomized males. Stimulation induced by mating and in vitro oocyte maturation produced the optimal oocyte recipient for SCNT. Although nuclear injection and cell fusion produced mid-term fetuses at equivalent rates (approximately 3-4%), only cell fusion gave rise to healthy surviving clones. Single cell fusion rates and the efficiency of SCNT were also enhanced by placing two somatic cells into the perivitelline space. These species-specific modifications facilitated the birth of live, healthy, and fertile cloned ferrets. The development of microsatellite genotyping for domestic ferrets confirmed that ferret clones were genetically derived from their respective somatic cells and unrelated to their surrogate mother. With this technology, it is now feasible to begin generating genetically defined ferrets for studying transmissible and inherited human lung diseases. Cloning of the domestic ferret may also aid in recovery and conservation of the endangered black-footed ferret and European mink.

**Descriptors:** ferrets, cell nucleus transplantation, cloning, genetics, cell fusion, embryo transfer, fetal development, microinjections, oocytes.

Li, Z.Y., Q.S. Jiang, M.R. Sabet, Y.L. Zhang, T.C. Ritchie, and J.F. Engelhardt (2002). **Conditions for in vitro maturation and artificial activation of ferret oocytes.** *Biology of Reproduction* 66(5): 1380-1386. ISSN: 0006-3363.

**Descriptors:** ferrets, oocytes, in vitro maturation, artificial activation, cloning, conditions, animal modelling, lung diseases.

Li, Z., Q. Jiang, M.R. Sabet, Y. Zhang, T.C. Ritchie, and J.F. Engelhardt (2002). **Parthenogenetic development of ferret oocytes matured in vitro following electrical and chemical stimulation.** *Biology of Reproduction* 66(Supplement 1): 169. ISSN: 0006-3363.

**Descriptors:** ferret, oocytes, parthenogenetic development, electrical stimulation, matured in vitro, reproduction, meeting abstract.

**Notes:** 35th Annual Meeting of the Society for the Study of Reproduction, Baltimore, Maryland, USA; July 28-31, 2002.

Li, Z., M.R. Sabet, Q. Zhou, X. Liu, W. Ding, Y. Zhang, J.P. Renard, and J.F. Engelhardt (2003). **Developmental capacity of ferret embryos by nuclear transfer using g0/g1-phase fetal fibroblasts.** *Biology of Reproduction* 68(6): 2297-2303. ISSN: 0006-3363.

**Descriptors:** ferret embryos, nuclear transfer, developmental capacity, g0-g1 phase fetal fibroblasts, cloning, experimental protocols.

Li, Z., X. Sun, J. Chen, and J.F. Engelhardt (2004). **Electrofusion of mouse and ferret oocytes with cultured ferret fetal fibroblast cells and cumulus cells.** *Biology of Reproduction*(Sp. Iss. SI): 235. ISSN: 0006-3363.

**Descriptors:** ferret, mouse, oocytes, electrofusion, fetal fibroblast cells, cultured cumulus cells.

**Notes:** 37th Annual Meeting of the Society-for-the-Study-of-Reproduction, Vancouver, Canada; August 01 -04, 2004.

Lindeberg, H. (2003). *Embryo technology in the farmed European polecat (*Mustela putorius*)*. Dissertation, University of Kuopio: Kuopio, Finland. 110 p.

**Descriptors:** assisted reproductive technology in endangered mammals, Finland, polecats, animal models, cryopreservation, embryo transfer techniques.

**Notes:** Thesis.

Lindeberg, H., J. Aalto, S. Amstislavsky, K. Piltti, M. Jarvinen, and M. Valtonen (2003). **Surgical recovery and successful surgical transfer of conventionally frozen-thawed embryos in the farmed European polecat (*Mustela putorius*).** *Theriogenology* 60(8): 1515-1525. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Abstract:** Surgical transfer of in vivo produced conventionally frozen-thawed embryos of farmed European polecat (*Mustela putorius*) was investigated as a part of an ex-situ preservation program which has the long-

term aim of developing a genome resource bank for the endangered European mink (*Mustela lutreola*). Eighteen oestrous yearling European polecat donors were mated once daily on two consecutive days using 13 fertile males. The donors were surgically flushed for embryos 8-9 days after the first mating. The embryo recovery rate was 60% (116 embryos/193 corpora lutea). The embryos were cryopreserved with 1.5 M ethylene glycol in a programmable freezer using a conventional slow freezing protocol. The thawed embryos were surgically transferred either after dilution with 0.5 M sucrose or directly without removal of ethylene glycol. To induce ovulation, eight recipient females were mated once daily on two consecutive days with vasectomized males starting 7 or 8 days before embryo transfer. The recipients received 7-11 embryos each and three recipients delivered a total of nine pups after a gestation length of 44-46 days. The embryo survival rate was 10% (9 pups/93 frozen embryos). This report describes the first successful cryopreservation of embryos in the Mustelidae family resulting in viable offspring. The low embryo survival rate, however, indicates that the freezing-thawing protocol needs to be improved.

**Descriptors:** ferrets, embryo transfer, tissue and organ harvesting, breeding, cryopreservation, ethylene glycol, gestational age, litter size, ovulation induction, uterus surgery.

Lindeberg, H., S. Amstislavsky, M. Jarvinen, J. Aalto, and M. Valtonen (2002). **Surgical transfer of in vivo produced farmed European polecat (*Mustela putorius*) embryos.** *Theriogenology* 57(9): 2167-2177. ISSN: 0093-691X. **NAL Call Number:** QP251.A1T5

**Abstract:** Surgical embryo transfer of farmed European polecat (*Mustela putorius*) was investigated as part of an ex situ preservation project. The long-term objective of the project is to develop effective technology for ex situ conservation of the European mink (*Mustela lutreola*), which is a highly endangered aboriginal European species. Twenty European polecat females, which served as a model species for the European mink, were humanely killed 4-9 days after first mating and embryos were recovered from oviducts and uteri. Donor-recipient pairs (n = 16) were generated by mating the donors (n = 20) once a day for 2 consecutive days with fertile males and by mating the corresponding recipients (n = 16) on the same days with vasectomized males. An embryo recovery rate of 70% (200 recovered embryos/284 corpora lutea) was achieved from 20 donors. Morulae and blastocysts were recovered between Days 5 and 9 after first mating and were regarded as the best developmental stages for uterine embryo transfer. A total of 172 embryos were transferred surgically under general anaesthesia into the ovarian third of the left uterine horn of 16 recipients with a thin glass capillary. Eleven recipients (69%) produced 72 pups equivalent to an average success rate of 42% (72 pups/172 transferred embryos). The average litter size was 4.5 (range 0-9). These results with this model species, farmed European polecat, demonstrate the potential of embryo transfer as an effective method for the preservation of the endangered European mink (*M. lutreola*). These species are closely related and have a similar reproductive physiology. However, success of applying embryo transfer in conserving European mink is still dependent on further studies both into its reproductive physiology and developing of improved flushing techniques for anaesthetized donors and the successful transfer of frozen-thawed embryos.

**Descriptors:** *Mustela*, embryo transfer, surgery, endangered species, wildlife management, animal models, morula, blastocyst, embryogenesis, ovulation.

Lindeberg, H. and M. Jarvinen (2003). **Early embryonic development and in vitro culture of in vivo produced embryos in the farmed european polecat (*Mustela putorius*).** *Theriogenology* 60(5): 965-975. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Descriptors:** European polecat, farmed, early embryonic development, in vitro culture, in vivo produced embryos, mink, technique.

Lisovschi Chelesanu, C., A. Damian, and C. Berghes (2002). **Morphostructural features of the ferret ovary.** *Buletinul Universitatii De Stiinte Agricole Si Medicina Veterinara Cluj Napoca Seria Medicina Veterinara* 58: 674-683.

**Descriptors:** *Mustela putorius*, anatomy and histology of ovaries, ferrets.

**Language of Text:** Romanian.

Nakai, M., J.K. Van Cleeff, and J.M. Bahr (2004). **Stages and duration of spermatogenesis in the domestic ferret (*Mustela putorius furo*).** *Tissue and Cell* 36(6): 439-446. ISSN: 0040-8166.

**Abstract:** Classification of seminiferous tubules is the basis for understanding normal and abnormal spermatogenesis. The aim of the present study was to determine spermatogenic stages and the duration of the cycle in the domestic ferret using bromodeoxyuridine (BrdU) as a tracer. Eleven adult male ferrets that were maintained in a breeding condition were used. Testicular sections were stained with the periodic acid-Schiff reaction for light microscopy. To determine the cycle duration, six ferrets were injected intraperitoneally with BrdU, and testes were collected 3h later and 10 days and 3h later. BrdU was detected by immunohistochemistry. Seminiferous tubules were classified into eight stages, and frequencies of stages I-VIII were 10.6, 2.2, 7.9, 13.1, 22.3, 21.9, 14.0 and 8.0%, respectively. The most advanced BrdU-labeled cells at 3h post-injection were leptotene spermatocytes in stage VI and those at 10 days and 3h were pachytene spermatocytes in stage V. From differences in stage frequency and BrdU staining frequency between two time points, the duration of one cycle was estimated to be 13.0 days. The present observations indicate that stages and the cycle duration of the ferret spermatogenesis are similar to those reported in other carnivores.

**Descriptors:** ferrets physiology, seminiferous tubules cytology, spermatocytes cytology, spermatogenesis physiology, bromodeoxyuridine metabolism, stages, duration.

Piltili, K., J. Aalto, M. Jarvinen, H. Korhonen, V. Kuronen, H. Lindeberg, S. Amstislavsky, Y. Ternovskaya, M. Valtonen, and M. Halmekyto (2003). **Nuclear maturation of european polecat (*Mustela putorius*) in vivo oocytes and success in using mustelid hybrids as recipients for embryo transfer.** *Theriogenology* 59(1): 403. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Descriptors:** European polecat, nuclear maturation, in vivo oocytes, mustelid hybrids, recipients, reproduction, embryo transfer.

**Notes:** Annual Conference of the International Embryo Transfer Society, Auckland, New Zealand; January 11-15, 2003.

Prohaczik, A., K. Fodor, M. Kulcsar, and G. Huszenicza (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei. Irodalmi attekintes. 1. A faj bemutatasa, taplalasa es ivari mukodesenek elettana. [Reproduction, genital malfunctions and endocrine disorders of domestic ferret (*Mustela putorius furo*). Literature review. 1. Biology, zootaxonomy, nutrition and physiology of reproduction].** *Magyar Allatorvosok Lapja* 126(6): 353-363. ISSN: 0025-004X.

**Descriptors:** ferret, biology, endocrine diseases, female genital diseases, nutrition, reproduction, reviews, taxonomy.

**Language of Text:** Hungarian; Summary in English.

Prohaczik, A., M. Kulcsar, and G. Huszenicza (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei: irodalmi attekintes. 4. Endokrin eredetu borelvaltozasok, hormonalis megbetegedések. [Reproduction, genital malfunctions and endocrine disorders of domestic ferrets (*Mustela putorius furo*): Literature review. 4. Endocrine skin lesions, hormonal diseases].** *Magyar Allatorvosok Lapja* 126(9): 553-560. ISSN: 0025-004X.

**Descriptors:** ferrets, female genital diseases, male genital diseases, endocrine diseases, hormonal diseases, reviews.

**Language of Text:** Hungarian; Summary in English.

**Notes:** English titles for journal articles are on p. 513 in the contents.

Prohaczik, A., M. Kulcsar, and G. Huszenicza (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei. Irodalmi attekintes. 2. Ivarszervi mukodeszavarok, megbetegedések. [Reproduction, genital malfunctions and endocrine disorders of domestic ferret (*Mustela putorius furo*). Literature review. 2. Pathology of reproduction].** *Magyar Allatorvosok Lapja* 126(6): 364-369. ISSN: 0025-004X.

**Descriptors:** ferret, genital diseases, endocrine disorders, genital malfunctions, pregnancy, pyometra, reproductive disorders, reviews, pathology.

**Language of Text:** Hungarian; Summary in English.

Prohaczik, A., M. Kulcsar, and G. Huszenicza (2004). **A vadaszgoreny (*Mustela putorius furo*) ivari mukodesenek**

**jellemzoi es befolyasolasanak lehetosegei. [Endocrine treatment procedures used to suppress the cyclic ovarian function in domestic ferrets (*Mustela putorius furo*)].** *Animal Breeding and Feeding* 53(2): 190-191. ISSN: 0230-1814.

**Descriptors:** ferrets, endocrine treatments, suppress cyclic ovarian function, reproduction.

**Language of Text:** Hungarian; Summary in English.

**Notes:** Proceedings of the 10th Meeting of the Hungarian Society for Animal Reproduction 'From Gametes until Birth', Kiskunmajsa, Hungary, 14-15 November 2003.

Prohaczik, A., M. Kulcsar, C. Juhasz, and G. Huszenicza (2004). **A vadaszgoreny (*Mustela putorius furo*) nemi mukodese, valamint gyakoribb ivarszervi es hormonalis megbetegedesei. Irodalmi attekintes. 3. A nem kivant ivarzas megelőzesenek lehetosegei es korlatai. [Reproduction, genital malfunctions and endocrine disorders of domestic ferret (*Mustela putorius furo*). Literature review. 3. Options and limitations in suppression of ovarian activity].** *Magyar Allatorvosok Lapja* 126(7): 419-423. ISSN: 0025-004X.

**Descriptors:** ferrets, genital malfunctions, endocrine diseases, female genital diseases, suppression of ovarian activity, reproductive disorders, reviews.

**Language of Text:** Hungarian; Summary in English.

Prohaczik, a., M. Kulcsar, T. Trigg, and G. Huszenicza (2003). **Treatments suppressing ovarian activity in ferret (*Mustela putorius furo*).** *Reproduction in Domestic Animals* 38(4): 331. ISSN: 0936-6768.

**Descriptors:** ferret, reproductive system, reproduction, ovarian activity, treatments suppressing, endocrine disease, spaying, clinical techniques, estrus cycle, ovulation, meeting abstract.

**Notes:** 7th Annual Conference of the European Society for Domestic Animal Reproduction, Belfield, Dublin, Ireland; September 04-06, 2003.

Prohaczik, A., M. Kulcsar, T. Trigg, and G. Huszenicza (2003). **Endocrine treatment procedures used to suppress the cyclic ovarian function in domestic ferrets (*Mustela putorius furo*).** *Proceedings of the Institute for Zoo and Wildlife Research, Berlin*(5): 407-408.

**Descriptors:** ferrets, cyclic ovarian function, suppress, endocrine treatment procedures.

**Notes:** Erkrankungen der Zootiere: Verhandlungsbericht des 41. Internationalen Symposiums über die Erkrankungen der Zoo- und Wildtiere, Rome, Italy, 28 May - 1 June, 2003.

Santymire, R.M., P.E. Marinari, J.S. Kreeger, D.E. Wildt, and J. Howard (2006). **Sperm viability in the black-footed ferret (*Mustela nigripes*) is influenced by seminal and medium osmolality.** *Cryobiology* 53(1): 37-50. ISSN: 0011-2240.

**Abstract:** Fundamental knowledge of spermatozoa cryobiology can assist with optimizing cryopreservation protocols needed for genetic management of the endangered black-footed ferret. Objectives were to characterize semen osmolality and assess the influence of two media at various osmolalities on sperm viability. We examined the influence of Ham's F10 +Hepes medium (H) at 270, 400, 500 or 700 mOsm (adjusted with sucrose, a nonpermeating cryoprotectant) and TEST Yolk Buffer (TYB) with 0% (300 mOsm) versus 4% (900 mOsm) glycerol (a permeating cryoprotectant). Electroejaculates (n=16) were assessed for osmolality using a vapor pressure osmometer. For media comparison, semen (n=5) was collected in TYB 0%, split into six aliquots, and diluted in H270, H400, H500, H700, and TYB 0% or TYB 4%. Each sample was centrifuged (300 g, 8 min), resuspended in respective medium, and maintained at 37 degrees C for 3h. Sperm motility and forward progression were monitored every 30 min for 3h post-washing. Acrosomal integrity was monitored at 0 and 60 min post-washing. Results demonstrated that black-footed ferret semen has a comparatively high osmolality (mean+/-SEM, 513.1+/-32.6 mOsm; range, 366-791 mOsm). Ferret spermatozoa were sensitive to hyperosmotic stress. Specifically, sperm motility was more susceptible (P<0.01) to hyperosmotic conditions than acrosomal integrity, and neither were influenced (P>0.05) by hypotonic solutions. Exposure to TYB 4% glycerol retained more (P<0.01) sperm motility than a hyperosmotic Ham's (700 mOsm). These findings will guide the eventual development of assisted breeding with cryopreserved sperm contributing to genetic management of this rare species.

**Descriptors:** ferrets, cell survival, drug effects, physiology, semen, preservation methods, spermatozoa physiology, glucose, pharmacology, osmolar concentration, sperm motility, drug effects, spermatozoa cytology.

Santymire, R.M., P.E. Marinari, J.S. Kreeger, D.E. Wildt, and J.G. Howard (2004). **Determining semen osmolality and effect of medium osmolality on sperm viability in the black-footed ferret (*Mustela nigripes*)**. *Journal of Andrology*(Suppl. S): 91. ISSN: 0196-3635.

**Descriptors:** black-footed ferret, reproduction, semen osmolality, medium osmolality, sperm viability, meeting abstract.

**Notes:** 29th Annual Meeting of the American Society of Andrology, Baltimore, MD, USA; April 17-20, 2004.

Schulz, L.C. and J.M. Bahr (2003). **Glucose-6-phosphate isomerase is necessary for embryo implantation in the domestic ferret**. *Proceedings of the National Academy of Sciences of the United States of America* 100(14): 8561-8566. ISSN: 0027-8424.

**Abstract:** The mechanism of implantation in carnivores is poorly understood. However, a previously unidentified 60-kDa protein has been shown to be necessary for embryo implantation in ferrets. Here we identify this protein as glucose-6-phosphate isomerase (GPI). GPI is expressed by the corpus luteum on days 6-9 of pregnancy, the time at which implantation-promoting activity has been found in corpora lutea. Passive immunization against GPI reduced the number of implantation sites in pregnant ferrets in a dose-dependent manner. GPI is a multifunctional protein. Although first identified for its role in glycolysis, GPI has since been implicated in neural growth, lymphocyte maturation, and metastasis. This study demonstrates a previously uncharacterized function of this protein that may represent the natural motility-stimulating activity that has been co-opted by tumor cells.

**Descriptors:** ferrets, corpus luteum, embryo implantation, glucose 6 phosphate isomerase physiology, amino acid sequence, base sequence, cell movement, chickens, embryo transfer, glucose 6 phosphate isomerase genetics, immunology, immunization, ovariectomy, pseudopregnancy.

Sirivaidyapong, S. and T. Swangchan uthai (2003). **The estrous cycle and estrogen toxicity during estrus in female ferret**. In: *Proceedings of 41st Kasetsart University Annual Conference, Subject: Animals and Veterinary Medicine, February 3, 2003-February 7, 2003*, Kasetsart University: Bangkok, Thailand, p. 554-562. ISBN: 9745372412.

**Descriptors:** ferrets, oestrous cycle, oestrus, reproductive disorders, oestrus toxicity, treatment, reproductive cycle, photoperiod.

**Language of Text:** Thai; Summary in English.

Sun, X., Z. Li, J. Chen, W. Ding, and J.F. Engelhardt (2004). **Relationship among chromatin configuration, oocyte size, and cumulus morphology in ferret cumulus-oocyte complexes**. *Biology of Reproduction*(Sp. Iss. SI): 256. ISSN: 0006-3363.

**Descriptors:** ferrets, reproductive system, oocyte size, chromatin configuration, cumulus morphology, reproduction.

**Notes:** 37th Annual Meeting of the Society-for-the-Study-of-Reproduction, Vancouver, Canada; August 01 -04, 2004.

Van Cleeff, J.K. and J.M. Bahr (2004). **Embryonic implantation in the domestic ferret requires a threshold prolactin concentration**. *Biology of Reproduction*(Sp. Iss. SI): 152-153. ISSN: 0006-3363.

**Descriptors:** ferret, embryonic implantation, prolactin concentration, reproduction in domestic ferrets.

**Notes:** 37th Annual Meeting of the Society-for-the-Study-of-Reproduction, Vancouver, Canada; August 01 -04, 2004.

Woodley, S.K. and M.J. Baum (2003). **Effects of sex hormones and gender on attraction thresholds for volatile anal scent gland odors in ferrets**. *Hormones and Behavior* 44(2): 110-118. ISSN: 0018-506X.

**Descriptors:** ferrets, sex hormones, gender attraction, anal scent gland, odors, attraction thresholds, mate recognition.

Woodley, S.K. and M.J. Baum (2002). **Estrogen increases attraction thresholds for volatile anal scent gland odors in male and female ferrets**. *Hormones and Behavior* 41(4): 496-497. ISSN: 0018-506X.

**Descriptors:** ferrets, male, female, estrogen, attraction, increases, olfactory sensitivity, scent gland odor, attraction threshold, meeting abstract.

**Notes:** Annual Meeting of the Society for Behavioral Neuroendocrinology, Amherst, MA, USA; June 26-30, 2002.

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### Research

Ball, R.S. (2006). **Issues to consider for preparing ferrets as research subjects in the laboratory.** *ILAR Journal* 47(4): 348-357. ISSN: 1084-2020.

**NAL Call Number:** QL55.A1I43

**Descriptors:** ferrets, research subjects, issues, concerns, preparing, laboratory.

Burr, D.H., D. Rollins, L.H. Lee, D.L. Pattarini, S.S. Walz, J.H. Tian, J.L. Pace, A.L. Bourgeois, and R.I. Walker (2005). **Prevention of disease in ferrets fed an inactivated whole cell *Campylobacter jejuni* vaccine.** *Vaccine* 23(34): 4315-4321. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Ferrets were used to demonstrate the potential of a killed whole cell vaccine prepared from *Campylobacter jejuni* to protect against disease. *C. jejuni* strain 81-176 was grown in BHI broth, formalin-fixed, and resuspended in PBS to a concentration of 10(10) cells per ml. This vaccine (CWC) or live organisms were delivered orally with a nasogastric tube into anesthetized animals treated to reduce gastric acidity and intestinal motility. When 5x10(10) CFU of the vaccine strain (Lior serotype 5) or one of two other serotypes, CGL-7 (Lior 4) or BT44 (Lior 9), was used to challenge the ferrets, all of the animals developed a mucoid diarrhea. If the animals had been challenged with 5x10(9) CFU of the homologous strain 1 month before challenge with 10(10) CFU, 80-100% protection against disease was seen. This protection was also obtained after an initial exposure to the 81-176 strain followed by challenge with either of the heterologous strains. CWC was used to see if protection demonstrated with the live organisms could be produced with the non-living preparation. When 10(9) cells of CWC was given as two doses 7 days apart with or without 25µg of a coadministered mucosal adjuvant, LT(R192G), only 40-60% of the animals were protected. If the regimen was changed to four doses given 48h apart, 80% of the animals were free of diarrhea after subsequent challenge. Increasing the number of cells in the four dose regimen to 10(10) cells did not improve protection. Animals given four doses of 10(10) cells combined with LT(R192G) were subsequently challenged with 10(10) cells of the homologous strain or the heterologous strain CGL-7. The CWC protected against both strains. Serum IgG antibody titers determined by ELISA showed little increase following the CWC four dose vaccination regimen, compared to animals given one dose of the live organism. On subsequent challenge, however, both CWC vaccinated and live-challenged ferrets showed comparable antibody titer increases above those obtained following the initial challenge or vaccination. Western blots were used to show that the immunodominant antigen in vaccinated animals was a 45kDa protein, while in ferrets challenged with live organisms the immunodominant antigen was a 62kDa protein. These data show that the CWC can be used to protect against disease caused by *Campylobacter*. They also show that protection and serum IgG responses do not depend upon the use of the mucosal adjuvant and that cross protection among some of the major serotypes of *Campylobacter* responsible for human disease is possible.

**Descriptors:** ferrets, bacterial vaccines, immunology, campylobacter infections, *Campylobacter jejuni*, immunoglobulin g, inactivated immunology.

Herlocher, M.L., R. Truscon, S. Elias, H.L. Yen, N.A. Roberts, S.E. Ohmit, and A.S. Monto (2004). **Influenza viruses**

**resistant to the antiviral drug oseltamivir: Transmission studies in ferrets.** *Journal of Infectious Disease* 190(9): 1627-1630. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** Three type A influenza viruses, each of which has a distinct neuraminidase-gene mutation and is resistant to the neuraminidase inhibitor oseltamivir, have been isolated. Previously, in the ferret model, an R292K mutant of a type A (H3N2) virus was not transmitted under conditions in which the wild-type virus was transmitted. This model was used to investigate whether the E119V mutant of a type A (H3N2) virus and the H274Y mutant of a type A (H1N1) virus would be transmitted under similar circumstances. Both mutant viruses were transmitted, although the H274Y mutant required a 100-fold-higher dose for infection of donor ferrets and was transmitted more slowly than was the wild type. Both the mutant and the wild-type viruses retained their genotypic characteristics.

**Descriptors:** ferrets, acetamides, antiviral agents, viral drug resistance, influenza A virus, orthomyxoviridae infections transmission, virology, disease models.

Johnson Delaney, C.A. (2002). **Update on ferret adrenal research.** *Exotic DVM* 4(3): 61-64. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, adrenal gland diseases, research, update, histopathology, neoplasms, surgical operations, therapy.

**Notes:** 4th Annual international conference on exotics (ICE2002), Key West, Florida, USA, 2002.

Lambkin, R., J.S. Oxford, S. Bossuyt, A. Mann, I.C. Metcalfe, C. Herzog, J.F. Viret, and R. Gluck (2004). **Strong local and systemic protective immunity induced in the ferret model by an intranasal virosome-formulated influenza subunit vaccine.** *Vaccine* 22(31-32): 4390-4396. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** The proliferation of influenza viruses causes costly, recurrent, annual epidemics. Current vaccines, mainly administered parenterally, have been shown to be suboptimal in terms of efficacy, particularly where local IgA responses are concerned. Recent investigations of virosomes as delivery systems for viral HA and NA antigens have demonstrated an improved immune response. This paper investigates the efficacy of a novel virosome-based intranasal influenza vaccine by its ability to reduce disease symptoms and its effect on viral shedding in nasal secretions of immunised ferrets. The use of ferrets in the study of influenza vaccines is based on the good comparability between ferret and human response to the disease. Intranasal, as opposed to parenteral, administration of a trivalent virosome-based subunit vaccine adjuvanted with HLT provides an almost total prevention of virus shedding combined with a high level of immunological protection against homologous virus challenge. The ease of application of an intranasal vaccine may have positive repercussions in the adoption of influenza vaccinations, particularly in 'at-risk' groups.

**Descriptors:** ferrets, orthomyxoviridae infections, intranasal administration, influenza A virus, influenza B virus, influenza vaccines, orthomyxoviridae infections, virus shedding.

Li, Z., X. Sun, J. Chen, G.H. Leno, and J.F. Engelhardt (2006). **Factors affecting the efficiency of embryo transfer in the domestic ferret (*Mustela putorius furo*).** *Theriogenology* 66(2): 183-190. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Abstract:** Embryo transfer (ET) to recipient females is a foundational strategy for a number of assisted reproductive technologies, including cloning by somatic cell nuclear transfer. In an attempt to develop efficient ET in domestic ferrets, factors affecting development of transferred embryo were investigated. Unilateral and bilateral transfer of zygotes or blastocysts in the oviduct or uterus was evaluated in recipient nulliparous or primiparous females. Developing fetuses were collected from recipient animals 21 days post-copulation and examined. The percentage of fetal formation was different ( $P < 0.05$ ) for unilateral and bilateral transfer of zygotes (71%) in nulliparous females with bilateral transfer (56%) in primiparous recipients. The percentage (90%) of fetal formation in nulliparous recipients following unilateral transfer of blastocysts was higher ( $P < 0.05$ ) than that observed in primiparous recipients with bilateral ET (73%). Notably, the percentage of fetal formation was higher ( $P < 0.05$ ) when blastocysts were transferred as compared to zygotes (90% versus 71%). Transuterine migration of embryos occurred following all unilateral transfers and also in approximately 50% of bilateral transfers with different number of embryos in each uterine horn. These data will help to facilitate the development of assisted reproductive strategies in the ferret and could lead to the use of this species for

modeling human disease and for conservation of the endangered Mustelidae species such as black-footed ferret and European mink.

**Descriptors:** ferret, embryo transfer, factors, efficiency, reproductive technologies, animal model.

Li, Z., X. Sun, J. Chen, X. Liu, S.M. Wisely, Q. Zhou, J.P. Renard, G.H. Leno, and J.F. Engelhardt (2006). **Cloned ferrets produced by somatic cell nuclear transfer.** *Developmental Biology* 293(2): 439-448. ISSN: 0012-1606.

**NAL Call Number:** 442.8 D49

**Abstract:** Somatic cell nuclear transfer (SCNT) offers great potential for developing better animal models of human disease. The domestic ferret (*Mustela putorius furo*) is an ideal animal model for influenza infections and potentially other human respiratory diseases such as cystic fibrosis, where mouse models have failed to reproduce the human disease phenotype. Here, we report the successful production of live cloned, reproductively competent, ferrets using species-specific SCNT methodologies. Critical to developing a successful SCNT protocol for the ferret was the finding that hormonal treatment, normally used for superovulation, adversely affected the developmental potential of recipient oocytes. The onset of Oct4 expression was delayed and incomplete in parthenogenetically activated oocytes collected from hormone-treated females relative to oocytes collected from females naturally mated with vasectomized males. Stimulation induced by mating and in vitro oocyte maturation produced the optimal oocyte recipient for SCNT. Although nuclear injection and cell fusion produced mid-term fetuses at equivalent rates (approximately 3-4%), only cell fusion gave rise to healthy surviving clones. Single cell fusion rates and the efficiency of SCNT were also enhanced by placing two somatic cells into the perivitelline space. These species-specific modifications facilitated the birth of live, healthy, and fertile cloned ferrets. The development of microsatellite genotyping for domestic ferrets confirmed that ferret clones were genetically derived from their respective somatic cells and unrelated to their surrogate mother. With this technology, it is now feasible to begin generating genetically defined ferrets for studying transmissible and inherited human lung diseases. Cloning of the domestic ferret may also aid in recovery and conservation of the endangered black-footed ferret and European mink.

**Descriptors:** ferrets, cell nucleus transplantation, cloning, genetics, cell fusion, embryo transfer, fetal development, microinjections, oocytes.

Liu, C., F. Lian, D.E. Smith, R.M. Russell, and X.D. Wang (2003). **Lycopene supplementation inhibits lung squamous metaplasia and induces apoptosis via up-regulating insulin-like growth factor-binding protein 3 in cigarette smoke-exposed ferrets.** *Cancer Research* 63(12): 3138-3144. ISSN: 0008-5472.

**Abstract:** Higher intake of lycopene is related to a lower risk of lung cancer in human studies. Lung cancer risk is associated with higher plasma levels of insulin-like growth factor I (IGF-I) and/or lower levels of IGF-binding protein 3 (IGFBP-3). However, little is known regarding whether lycopene can inhibit cigarette smoke-induced lung carcinogenesis through modulation of IGF-I/IGFBP-3, cell proliferation, and apoptosis. We investigated the effects of lycopene supplementation at a low dose (1.1 mg/kg/day, which is equivalent to an intake of 15 mg/day in humans) and a high dose (4.3 mg/kg/day, which is equivalent to 60 mg/day in humans) on plasma IGF-I/IGFBP-3 levels, histopathological changes, proliferating cellular nuclear antigen (PCNA) expression, BAD phosphorylation, and apoptosis (caspase 3 assay) in lungs of ferrets with or without cigarette smoke exposure for 9 weeks. We found that ferrets supplemented with lycopene and exposed to smoke had significantly higher plasma IGFBP-3 levels ( $P < 0.01$ ) and a lower IGF-I/IGFBP-3 ratio ( $P < 0.01$ ) than ferrets exposed to smoke alone. Both low- and high-dose lycopene supplementations substantially inhibited smoke-induced squamous metaplasia and PCNA expression in the lungs of ferrets. No squamous metaplasia or PCNA overexpression were found in the lungs of control ferrets or those supplemented with lycopene alone.

Furthermore, cigarette smoke exposure greatly increased BAD phosphorylation at both Ser(136) and Ser(112) and significantly decreased cleaved caspase 3 in the lungs of ferrets, as compared with controls. The elevated phosphorylation of BAD and down-regulated apoptosis induced by cigarette smoke in the lungs of ferrets was prevented by both low- and high-dose lycopene supplementations. Lycopene levels were increased in a dose-dependent manner in both plasma and lungs of ferrets supplemented with lycopene alone. However, lycopene levels were markedly lower in both plasma and lungs of ferrets supplemented with lycopene and exposed to smoke. Furthermore, smoke exposure increased cis isomers (26% for 13-cis and 22% for 9-cis) of lycopene in the lungs of ferrets, compared with that of ferrets supplemented with lycopene alone (20% for 13-cis and 14% for 9-cis). In conclusion, lycopene may mediate its protective effects against smoke-induced lung

carcinogenesis in ferrets through up-regulating IGFBP-3 and down-regulating phosphorylation of BAD, which promote apoptosis and inhibit cell proliferation.

**Descriptors:** ferrets, anticarcinogenic agents, apoptosis, carotenoids, adverse effects of smoke, anticarcinogenic agents, carrier proteins, caspases, cell division, dietary supplements, drug evaluation, lung metabolism, metaplasia, animal models, phosphorylation, post translational drug effects.

Liu, C., R.M. Russell, and X.D. Wang (2004). **Low dose beta-carotene supplementation of ferrets attenuates smoke-induced lung phosphorylation of JNK p38 MAPK and p53 proteins.** *Journal of Nutrition* 134(10): 2705-2710. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Descriptors:** ferrets, proteins, beta carotene, supplementation, smoke induced lung phosphorylation, low dose.

Liu, C., R.M. Russell, and X.D. Wang (2006). **Lycopene supplementation prevents smoke-induced changes in p53, p53 phosphorylation, cell proliferation, and apoptosis in the gastric mucosa of ferrets.** *Journal of Nutrition* 136(1): 106-111. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Abstract:** Cigarette smoking increases the risk for gastric cancer. Higher intakes or blood levels of lycopene are associated with a decreased risk of gastric cancer. However, the biological mechanisms by which lycopene may protect against gastric carcinogenesis are poorly understood. We evaluated the effects of lycopene supplementation on smoke-induced changes in protein levels of p53, p53 target genes (p21<sup>Waf1/Cip1</sup> and Bax-1), cell proliferation, and apoptosis in the gastric mucosa of ferrets. Ferrets were assigned to cigarette smoke exposure or to no exposure and to no, low-dose, or high-dose lycopene supplementation (2 x 3 factorial design) for 9 wk. Lycopene concentrations were significantly elevated in a dose-dependent manner in the gastric mucosa of ferrets supplemented with lycopene alone, but were markedly reduced in ferrets supplemented with lycopene and exposed to smoke. Although ferrets were given lycopene containing 95% all-trans isomers, cis isomers were the predominant forms in the gastric mucosa. Total p53 and phosphorylated p53 levels were greater in ferrets exposed to smoke alone than in all other groups. Levels were [approximately]300 and 500% of the controls, respectively. However, smoke-elevated total p53 and phosphorylated p53 were markedly attenuated by both doses of lycopene. p21<sup>Waf1/Cip1</sup>, Bax-1, and cleaved caspase 3 were substantially decreased, whereas cyclin D1 and proliferating cellular nuclear antigen (PCNA) were increased in ferrets exposed to smoke alone. Lycopene prevented smoke-induced changes in p21<sup>Waf1/Cip1</sup>, Bax-1, cleaved caspase 3, cyclin D1, and PCNA in a dose-dependent fashion. These data indicate that lycopene may prevent smoke exposure-induced changes in p53, p53 phosphorylation, p53 target genes, cell proliferation, and apoptosis in the gastric mucosa of ferrets.

**Descriptors:** ferrets, animal disease models, smoking habit, lycopene, dietary supplements, protein phosphorylation, cell proliferation, apoptosis, human health, gastric mucosa, cigarettes, gastric cancer, human diseases, chemoprevention, gene expression, proliferating cell nuclear antigen, cyclins, animal proteins.

Ljungberg, K., C. Kolmskog, B. Wahren, G. van Amerongen, M. Baars, A. Osterhaus, A. Linde, and G. Rimmelzwaan (2002). **DNA vaccination of ferrets with chimeric influenza A virus hemagglutinin (H3) genes.** *Vaccine* 20(16): 2045-2052. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Recently a technology was established based on homologous recombination that allowed the rapid generation of chimeric HA genes of influenza viruses, containing the antigenic determinants obtained from various influenza virus A (H3N2) viruses. In the present report plasmids were generated using a H3 HA vector handle and the hypervariable regions of two genetically distinct influenza A H3N2 viruses, A/Stockholm/7/97 and A/Netherlands/18/94. In a ferret model it was shown that immunisation with plasmid DNA encoding chimeric HA indeed elicited antibody responses specific for the virus from which the hypervariable region with the antigenic determinants were obtained. After DNA-immunisation of the ferrets, protective immunity against infection with influenza virus A/Netherlands/18/94 was evaluated.

**Descriptors:** ferrets, hemagglutinin glycoproteins, influenza virus genetics, influenza A virus, influenza vaccines, DNA vaccines, enzyme linked immunosorbent assay, lymphocyte activation, genetic recombination, T lymphocytes.

Mann, A., A.C. Marriott, S. Balasingam, R. Lambkin, J.S. Oxford, and N.J. Dimmock (2006). **Interfering vaccine (defective interfering influenza A virus) protects ferrets from influenza, and allows them to develop solid immunity to reinfection.** *Vaccine* 24(20): 4290-4296. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Defective interfering (DI) virus RNAs result from major deletions in full-length viral RNAs that occur spontaneously during de novo RNA synthesis. These RNAs are packaged into virions that are by definition non-infectious, and are delivered to cells normally targeted by the virion. DI RNAs can only replicate with the aid of a coinfecting infectious helper virus, but the small size of DI RNA allows more copies of it to be made than of its full-length counterpart, so the cell produces defective virions in place of infectious progeny. In line with this scenario, the expected lethal disease in an influenza A virus-mouse model is made subclinical by administration of DI virus, but animals develop solid immunity to the infecting virus. Hence DI virus has been called an 'interfering vaccine'. Because interfering vaccine acts intracellularly and at a molecular level, it should be effective against all influenza A viruses regardless of subtype. Here we have used the ferret, widely acknowledged as the best model for human influenza. We show that an interfering vaccine with defective RNAs from an H3N8 virus almost completely abolished clinical disease caused by A/Sydney/5/97 (H3N2), with abrogation of fever and significant reductions in clinical signs of illness. Animals recovered fully and were solidly immune to reinfection, in line with the view that treatment converts the otherwise virulent disease into a subclinical and immunizing infection.

**Descriptors:** influenza vaccines, administration, dosage, influenza virus A immunology, ferrets, mice, orthomyxoviridae infections, immunology.

Olsen, A.K. (2005). **Ilderen som forsogsdyr. [Ferrets as experimental animals].** *Dansk Veterinaertidsskrift* 88(6): 8-9. ISSN: 0106-6854.

**Descriptors:** ferrets, research, brain, disease models, laboratory animals, stomach ulcers, vaccination, viruses.

**Language of Text:** Danish.

Philipp, R., C. Distler, and K.P. Hoffmann (2006). **A motion-sensitive area in ferret extrastriate visual cortex: An analysis in pigmented and albino animals.** *Cerebral Cortex* 16(6): 779-790. ISSN: 1047-3211.

**Abstract:** In search of the neuronal substrate for motion analysis in the ferret (*Mustela putorius furo*), we extracellularly recorded from extrastriate visual cortex in five pigmented and two albino ferrets under general anaesthesia and paralysis. Visual stimulation consisted of large area random dot patterns moving either on a circular path in the frontoparallel plane or expanding and contracting radially. Strongly direction-selective neurons were recorded in a circumscribed area in and just posterior to the suprasylvian sulcus, thus named by us the posterior suprasylvian area (area PSS). Altogether, we recorded 210 (90%) and 95 (72%) PSS neurons in pigmented and albino ferrets, respectively, that were direction selective. In these neurons responses during random dot pattern stimulation in the preferred direction were at least twice as strong than stimulation in the non-preferred direction. Response strength in preferred direction and tuning sharpness of PSS neurons in albinos were significantly reduced when compared to pigmented animals (median values: 34.1 versus 14.8 spikes/s and 142 versus 165 degrees for pigmented and albino ferrets, respectively). Inter-spike-intervals during visual stimulation were significantly shorter in pigmented (median 9 ms) than in albino PSS neurons (median 14 ms). Our data indicate that area PSS may play a crucial role in motion perception in the ferret.

**Descriptors:** ferrets, albinism, ocular physiopathology, motion perception, nerve net, visual cortex, evoked potentials, photic stimulation, pigmentation.

Riggs, S.M., J.J. Heatley, J. Nevarez, and M.A. Mitchell (2002). **Ferret blood collection: A quick and simple technique.** *Exotic DVM* 4(6): 6-7. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferret, blood collection technique, anesthesia, blood chemistry, blood sampling.

Schoemaker, N. and A. Kuijten (2004). **Onderzoek naar nieuwe behandeling voor fretten met bijniertumoren. [Research to find new treatments for ferrets with adrenal gland tumors].** *Tijdschrift Voor Diergeneeskunde* 129(21): 722. ISSN: 0040-7453.

**Descriptors:** ferrets, adrenal gland neoplasms, research, adrenal gland neoplasms, surgery, therapy, adrenalectomy methods, antineoplastic agents, hormonal therapeutic use, leuprolide therapeutic use,

Netherlands, treatment outcome.

**Language of Text:** Dutch.

Vos, A., T. Muller, J. Cox, L. Neubert, and A.R. Fooks (2004). **Susceptibility of ferrets (*Mustela putorius furo*) to experimentally induced rabies with European Bat Lyssaviruses (EBLV).** *Journal of Veterinary Medicine, B, Infectious Diseases and Veterinary Public Health* 51(2): 55-60. ISSN: 0931-1793.

**Abstract:** Twenty ferrets (*Mustela putorius furo*) were inoculated by intramuscular (i.m.) injection with European Bat Lyssaviruses (EBLV) type-1 and 2 using 10(4.0) foci-forming units (FFU) EBLV-2 (n = 6), 10(4.0) FFU EBLV-1 (n = 7) and 10(6.0) FFU EBLV-1 (n = 7). Furthermore, 15 mice received 10(2.5) FFU EBLV-2 (n = 5), 10(2.5) FFU EBLV-1 (n = 5) and 10(4.5) FFU EBLV-1 (n = 5) by i.m. inoculation. All ferrets and mice receiving the higher dose of EBLV-1 succumbed to infection. In contrast, only three of seven ferrets and two of five mice inoculated experimentally with the lower EBLV-1 dose died. By comparison, all of the EBLV-2 infected ferrets and four of five mice survived infection. All 20 infected ferrets seroconverted. Using sensitive molecular tools, the virus was detected in different tissues, but it could not be found in any saliva samples taken during the 84-day observation period.

**Descriptors:** ferrets, lyssavirus, rhabdoviridae infections, DNA, viral analysis, disease susceptibility.

Wang, X.D. (2005). **Can smoke-exposed ferrets be utilized to unravel the mechanisms of action of lycopene.** *Journal of Nutrition* 135(8): 2053S-2056S. ISSN: 0022-3166.

**NAL Call Number:** 389.8 J82

**Descriptors:** tomato products, lycopene, anticarcinogenic activity, lung cancer, ferrets, animal models, smoking habit, mechanism of action, dosage, metabolites, blood chemistry, lungs, cell proliferation, epidemiology.

**Notes:** In the special section: "Promises and perils of lycopene/tomato supplementation and cancer prevention." Presented at a conference held February 17-18, 2005, Bethesda, Maryland.

Wolf, G. (2002). **The effect of low and high doses of beta-carotene and exposure to cigarette smoking on the lungs of ferrets.** *Nutrition Reviews* 60(3): 88-90. ISSN: 0029-6643.

**NAL Call Number:** 389.8 N953

**Abstract:** When the diets of ferrets were supplemented with large (pharmacologic) daily doses of beta-carotene (BC) for 6 months, the levels of retinoic acid and the retinoic acid receptor beta declined significantly in lung tissues. Indicators of cell proliferation (c-jun and c-fos proteins and others) increased. Histologic observations showed that feeding high doses of BC resulted in keratinized squamous metaplasia in the lung tissues. When high-doses of BC were combined with daily exposure to cigarette smoke, the BC effects were greatly accentuated. These results may lead to an explanation of the increased incidence of lung cancer in two large independent epidemiologic studies of smokers in which pharmacologic doses of BC were given.

**Descriptors:** beta carotene, tobacco smoking, passive smoking, lungs, animal tissues, receptors, vitamin supplements, ferrets, literature reviews, lung tissues.

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## Information Resources on the Care and Welfare of Ferrets

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### Veterinary

- Anon. (2004). **Rely on clinical skills to diagnose ferret adrenal disease.** *DVM* 35(6): 16s-19s. ISSN: 0012-7337.  
**Online:** <http://veterinarynews.dvm360.com/dvm/Medicine/Rely-on-clinical-skills-to-diagnose-ferret-adrenal/ArticleStandard/Article/detail/126823?contextCategoryId=44832>  
**Descriptors:** ferret, adrenal disease, diagnosis, clinical skills.
- Antinoff, N. and K. Hahn (2004). **Ferret oncology: Diseases, diagnostics, and therapeutics.** *Veterinary Clinics of North America. Exotic Animal Practice* 7(3): 579-625, Vi. ISSN: 1094-9194.  
**NAL Call Number:** SF997.5.E95 E97  
**Abstract:** Many standard diagnostic and chemotherapeutic protocols can be adapted for use in ferrets. Unique anatomic and clinical features dictate modification of protocols, but should not prohibit diagnosis or treatment. Ferrets may be the easiest of nontraditional species to treat with chemotherapeutics. We can provide more options for our patients, with improved quality of life and longer survival times than ever before. Although clients are never happy to hear the diagnosis of "cancer," it is no longer a word that condemns their beloved pet.  
**Descriptors:** ferrets, neoplasms, diagnosis, diseases, oncology, chemotherapeutics.
- Bennett, R.A. (2002). **Ferret abdominal surgical procedures.** *Proceedings of the North American Veterinary Conference* 16: 957-960.  
**NAL Call Number:** SF605.N672  
**Descriptors:** ferrets, abdomen, surgical operations.  
**Notes:** In the volume: Small animal and exotics. Part of a three volume set. Meeting held January 12-16, 2002, Orlando, Florida.
- Bennett, R.A. (2004). **Ferret soft tissue surgery.** In: *Small Animal and Exotics Book Two: Pain Management Zoonosis - Proceedings of the North American Veterinary Conference.*, Vol. 18, Eastern States Veterinary Association: Gainesville, USA, p. 1363-1366.  
**Descriptors:** ferret, soft tissue, surgery, adrenal glands, digestive tract, gastrointestinal diseases, neoplasms, prostate, spleen.  
**Notes:** North American Veterinary Conference, Volume 18, Orlando, Florida, USA, 17-21 January 2004.
- Bixler, H. and C. Ellis (2004). **Ferret care and husbandry.** *Veterinary Clinics of North America. Exotic Animal Practice* 7(2): 227-255, V. ISSN: 1094-9194.  
**NAL Call Number:** SF997.5.E95 E97  
**Abstract:** Convivial and playful, the ferret has cohabited with humans for hundreds of years. Maintenance of this mustelid's health and quality of life is paramount for the endurance of the human-animal bond. This review article for veterinary care givers, veterinarians, and staff, encompasses discussions on: husbandry, clinical techniques, prevalent diseases, history taking, physical examination, vaccination, and pain recognition. This article also enables the veterinary community to contribute to the care and welfare of ferret patients by offering facts to distinguish these animals from dogs and cats.

**Descriptors:** animal husbandry, ferrets, care, welfare, clinical techniques, diseases, physical examination, vaccination, pain recognition.

Burgess, M. and M. Garner (2002). **Clinical aspects of inflammatory bowel disease in ferrets.** *Exotic DVM* 4(2): 29-34. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, inflammatory bowel disease, diagnostic techniques, digestive diseases.

Burns, R., E.S. Williams, D. O'Toole, and J.P. Dubey (2003). ***Toxoplasma gondii* infections in captive black-footed ferrets (*Mustela nigripes*), 1992-1998: Clinical signs, serology, pathology, and prevention.** *Journal of Wildlife Diseases* 39(4): 787-797. ISSN: 0090-3558.

**NAL Call Number:** 41.9 W648

**Abstract:** An epizootic of toxoplasmosis occurred among 22 adult and 30 kit black-footed ferrets (*Mustela nigripes*) maintained under quarantine conditions at the Louisville Zoological Garden (Louisville, Kentucky, USA) in June, 1992. Black-footed ferrets appear to be highly susceptible to acute and chronic toxoplasmosis. Clinical signs were observed in 19 adults and six kits and included anorexia, lethargy, corneal edema, and ataxia. Two adults and six kits died with acute disease. High antibody titers to *Toxoplasma gondii* were detected by latex agglutination and modified agglutination assay in 10 black-footed ferrets. One adult and six kits that died with acute clinical signs were necropsied and *T. gondii*-like organisms were found microscopically in multiple organs. Diagnosis of toxoplasmosis was confirmed by immunohistochemical staining with anti-*T. gondii* antibodies and by ultrastructural examination. Although the source of *T. gondii* for black-footed ferrets was not identified, frozen uncooked rabbit was the most likely source. Chronic toxoplasmosis resulted in the death of an additional 13 black-footed ferrets that were adults during the epizootic. Affected animals developed chronic progressive posterior weakness and posterior ataxia 6-69 mo after the epizootic began.

Meningoencephalitis or meningoencephalomyelitis associated with chronic toxoplasmosis were identified at necropsy in all 13 ferrets. Precautions to prevent introduction of pathogens into the colony were insufficient to exclude *T. gondii*. Although toxoplasmosis may cause significant mortality in mustelids, the high mortality of black-footed ferrets in this epizootic was of concern due to their endangered status. This is the first detailed report of toxoplasmosis in black-footed ferrets.

**Descriptors:** ferrets, antibodies, blood protozoan, toxoplasmosis, agglutination tests, immunohistochemistry, Kentucky, latex fixation tests, liver parasitology.

Carmel, B. (2006). **Eosinophilic gastroenteritis in three ferrets.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 707-712. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Eosinophilic gastroenteritis (EGE) is a rarely reported condition of ferrets. This article reviews three cases of suspected EGE in ferrets, summarizes the presenting signs, differential diagnoses, and treatment options, and discusses some questions raised by this disease in ferrets. Immune suppression by means of prednisolone therapy is currently the treatment of choice.

**Descriptors:** Ferrets, eosinophilic gastroenteritis, signs, diagnosis, treatment.

Carpenter, J.W. and K.E. Quesenberry (Editors) (2004). ***Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery: Includes Sugar Gliders and Hedgehogs***, 2nd edition, Saunders: Philadelphia, PA, 461 p. ISBN: 0721693776.

**NAL Call Number:** SF997.5.F47 F47 2004

**Descriptors:** ferret diseases, rabbit diseases, rodent diseases, ferrets, rabbits, rodents, surgery.

Carroll, E.E., R.R. Dubielzig, and R.D. Schultz (2002). **Cats differ from mink and ferrets in their response to commercial vaccines: A histologic comparison of early vaccine reactions.** *Veterinary Pathology* 39(2): 216-227. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Early histologic changes in lesions at vaccine sites were compared in cats, mink, and ferrets. Twenty-four 4-month-old cats, 20 4-month-old mink, and 20 12-month-old ferrets were vaccinated with three rabies virus vaccines, two feline leukemia virus vaccines, alum adjuvant, and saline. Injection sites were excised at

selected time points up to 21 days postvaccination. Histologic examination of the tissue revealed significant differences among the cats, mink, and ferrets in the local response to the commercial vaccines. When compared with ferrets and mink, cats had more lymphocytes in response to all three rabies vaccines. Production of fibroblasts, collagen, and macrophages differed among the three killed aluminum-adsorbed vaccines in cats but did not differ significantly in mink or ferrets. Cats produced fewer binucleate cells than did mink or ferrets in response to the two adjuvanted leukemia virus vaccines. Differences seen in early tissue response of cats to commercial vaccines may be related to the increased predisposition of cats to vaccine-associated sarcomas.

**Descriptors:** cats, ferrets, leukemia virus, mink, rabies vaccines, viral vaccines, skin immunology, vaccine sites, lesions.

Castanheira de Matos, R.E. and J.K. Morrisey (2006). **Common procedures in the pet ferret.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(2): 347-365, Vii. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** The domestic ferret is an increasingly popular pet in North America and Europe and may easily be incorporated into the structure and workings of most small animal hospitals. Not only does treatment of ferrets provide case diversity and intellectual challenges to the veterinarian but it may increase revenue, because most ferret owners have several ferrets. The diagnostic and supportive care procedures used commonly in ferrets are similar to those used in dogs and cats. This article presents the common diagnostic and supportive care procedures used in ferrets, with special emphasis on some of the unique aspects that make these procedures easier to learn and perform.

**Descriptors:** ferrets, diseases, diagnosis, therapy, nutrition, differential, physical examination, instrumentation, procedures, supportive care.

Chiaravaccini, L., C. D' Agostino, and S. Perrucci (2003). **Aspetti parassitologici e clinici della coccidiosi e dell'otocariasi del furetto (*Mustela putorius furo*).** [Parasitological and clinical aspects of coccidiosis and auricular mange of the ferret (*Mustela putorius furo*)]. *Veterinaria* 17(3): 73-76. ISSN: 0391-3151.

**Descriptors:** ferret, coccidiosis, auricular mange, parasites, clinical aspects, examination, diagnosis, *Otodectes cynotis*, polecats, *Eimeria furonis*, *Isospora laidlawii*.

**Language of Text:** Italian; Summary in English.

Conn, M. (2004). **Resolution of chronic conjunctivitis in a ferret with a nasolacrimal duct obstruction.** *Exotic DVM* 6(1): 16-18. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferret, clinical aspects, conjunctivitis, diagnosis, drug therapy, case reports, nasolacrimal duct obstruction.

Cooper, J.E. (2002). **The ferret, and other small mammals--a European veterinarian's perspective.** *Proceedings of the North American Veterinary Conference* 16: 9-10.

**NAL Call Number:** SF605.N672

**Descriptors:** ferrets, small mammals, rodents, rabbits, veterinary services, Europe.

**Notes:** In the volume: Veterinary technicians & practice managers. Part of a three volume set. Meeting held January 12-16, 2002 in Orlando, Florida.

Cottrell, D.K. (2004). **Use of moxidectin (ProHeartReg. 6\*) as a heartworm adulticide in 4 ferrets.** *Exotic DVM* 6(5): 9-12. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, heartworms, clinical aspects, diagnosis, drug therapy, *Dirofilaria immitis*, moxidectin.

Dalrymple, E.F. (2004). **Pregnancy toxemia in a ferret.** *Canadian Veterinary Journal* 45(2): 150-152. ISSN: 0008-5286.

**NAL Call Number:** 41.8 R3224

**Abstract:** A late-gestation jill was presented for depression, anorexia, and weakness. The working diagnosis became pregnancy toxemia. Supportive care was initiated and an emergency cesarian section performed. Twelve live kits were delivered; however, all soon perished despite home care. Surgery and recovery are

discussed, including information regarding pregnancy toxemia in general.

**Descriptors:** ferrets, cesarean section, pre eclampsia, nutrition, newborn, diagnosis, differential, hysterectomy, ovariectomy, surgery, pregnancy outcome.

Darby, C. and V. Ntavlourou (2006). **Hepatic hemangiosarcoma in two ferrets (*Mustela putorius furo*)**. *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 689-694. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Two ferrets were presented to the authors' clinic. Hemoperitoneum was diagnosed in one ferret, and an abdominal mass was palpated in the other. One ferret was euthanized and necropsied, and one ferret underwent exploratory laparotomy and liver lobectomy. In both cases, the histopathologic diagnosis was hepatic hemangiosarcoma.

**Descriptors:** ferrets, hemangiosarcoma, hepatic, abdominal mass, laparotomy, diagnosis, liver lobectomy.

De Voe, R.S., L. Pack, and C.B. Greenacre (2002). **Radiographic and CT imaging of a skull associated osteoma in a ferret**. *Veterinary Radiology & Ultrasound* 43(4): 346-348. ISSN: 1058-8183.

**NAL Call Number:** SF757.8.A4

**Descriptors:** ferrets, case reports, skull, radiography, computed tomography, diagnostic value, biopsy, neoplasms, mandible.

Dunayer, E. (2004). **Ibuprofen toxicosis in dogs, cats, and ferrets**. *Exotic DVM* 99(7): 580 582, 584, 586. ISSN: 8750-7943.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, dogs, cats, ibuprofen, toxicosis.

Eatwell, K. (2004). **Two unusual tumours in a ferret (*Mustela putorius furo*)**. *Journal of Small Animal Practice* 45(9): 454-459. ISSN: 0022-4510.

**NAL Call Number:** 41.8 J8292

**Abstract:** This case report describes the clinical history, diagnosis and treatment of a ferret with a tumour of the right adrenal gland and insulinomas of the pancreas. Histopathology of both lesions confirmed the diagnoses. Clinical signs of the adrenal gland tumour were a swollen vulva, overgrooming, sexual activity and pruritus. The clinical signs suggesting insulinomas were collapse of the ferret, disorientation and ptyalism. A low blood glucose level assisted the diagnosis of insulinomas. This is believed to be the first reported case of concurrent insulinomas and adrenal gland tumour in a ferret in the United Kingdom.

**Descriptors:** ferrets, adenoma, adrenal gland neoplasms, insulinoma, pancreatic neoplasms, treatment outcome, surgery.

Fehr, M., A. Thiele, A. Gerdwilker, C. Rapsch, and A. Klawitter (2006). **Speichelzyste der Glandula zygomatica bei einem Frettchen (*Mustela putorius furo* L.)**. [Salivary mucocele (Zygomatic gland) in a ferret (*Mustela putorius furo* L.)]. *Kleintier-Praxis* 51(4): 210-215. ISSN: 0023-2076.

**Online:** <http://www.schaper-verlag.de>

**NAL Call Number:** 41.8 K67

**Descriptors:** ferret, salivary mucocele, clinical aspects, corneal ulcer, diagnosis, exophthalmos, salivary gland diseases, surgery, therapy.

**Language of Text:** German; Summary in English.

Funk, A. J, T. Rogers D, R. Dobbins M, and K. Boyd (2006). **Exophthalmos and corneal edema in a young ferret**. **Diagnosis: Glaucoma**. *Lab Animal* 35(9): 19, 20-21. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Descriptors:** ferret, corneal edema, exophthalmos, glaucoma, diagnosis.

Garcia, A., S.E. Erdman, S. Xu, Y. Feng, A.B. Rogers, M.D. Schrenzel, J.C. Murphy, and J.G. Fox (2002).

**Hepatobiliary inflammation, neoplasia, and argyrophilic bacteria in a ferret colony**. *Veterinary Pathology* 39(2): 173-179. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Hepatobiliary disease was diagnosed in eight of 34 genetically unrelated cohabitating pet ferrets (*Mustela putorius furo*) during a 7-year period. The eight ferrets ranged in age from 5 to 8 years and exhibited chronic cholangiohepatitis coupled with cellular proliferation ranging from hyperplasia to frank neoplasia. Spiral-shaped argyrophilic bacteria were demonstrated in livers of three ferrets, including two with carcinoma. Sequence analysis of a 400-base pair polymerase chain reaction product amplified from DNA derived from fecal bacteria from one ferret demonstrated 98% and 97% similarity to *Helicobacter cholecystus* and *Helicobacter* sp. strain 266-1, respectively. The clustering of severe hepatic disease in these cohabitating ferrets suggests a possible infectious etiology. The role of *Helicobacter* species and other bacteria in hepatitis and/or neoplasia in ferrets requires further study.

**Descriptors:** ferrets, helicobacter infections, *Helicobacter pylori*, liver diseases, bile duct neoplasms, biliary tract diseases, cholangiocarcinoma, cystadenoma, bacterial DNA, hepatitis, hyperplasia, immunohistochemistry, liver microbiology.

Garipis, N. and K.P. Hoffmann (2003). **Visual field defects in albino ferrets (*Mustela putorius furo*).** *Vision Research* 43(7): 793-800. ISSN: 0042-6989.

**Abstract:** The extent of the horizontal visual field was determined behaviourally in 4 pigmented and 5 albino ferrets (*Mustela putorius furo*, Carnivora, Mammalia) using perimetry. During binocular vision, all pigmented and three albino ferrets responded equally well to stimuli presented anywhere along the horizontal perimeter in the central 180 degrees of the visual field. The remaining two albinos had a visual field defect in the right hemifield (>30 degrees eccentricity). During monocular vision, a significant difference between the visual fields of pigmented and albino ferrets became apparent. In pigmented ferrets, the visual field of each eye included the ipsilateral (temporal) and a substantial portion of the contralateral (nasal) hemifield. In albinos, the visual field of each eye was limited to the ipsilateral hemifield and reactions to visual stimuli abruptly declined directly beyond the vertical meridian.

**Descriptors:** ferrets, albinism, vision disorders, perimetry methods, albino ferrets, visual field.

Garner, M.M. (2003). **Focus on diseases of ferrets.** *Exotic DVM* 5(3): 75-80. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, diseases, clinical aspects, glomerulonephritis, lymphatic diseases, mycobacterial diseases, neoplasms, otitis externa, infections.

**Notes:** International conference on exotics (ICE2003), Palm Beach, Florida, USA, 2003.

Good, K.L. (2002). **Ocular disorders of pet ferrets.** *Veterinary Clinics of North America. Exotic Animal Practice* 5(2): 325-339. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Ocular disorders in pet ferrets are becoming more widely recognized as the popularity of these animals as companions increases. Knowledge of the anatomy of ferrets and a thorough examination are critical to accurately diagnosing ocular disease. If recognized early, some conditions can be managed successfully. Veterinarians should continue to report ocular conditions that are encountered in this species to help increase knowledge about these disorders.

**Descriptors:** ferrets, eye anatomy, eye diseases, ferrets anatomy, conjunctivitis, glaucoma diagnosis, ophthalmology.

Graham, J., J. Fidel, and M. Mison (2006). **Rostral maxillectomy and radiation therapy to manage squamous cell carcinoma in a ferret.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 701-706. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** A 4-year-old, male, neutered ferret presented with squamous cell carcinoma of the right maxillary region associated with the tissues surrounding the upper canine tooth. A rostral maxillectomy was performed to excise the mass. Histopathologic examination showed questionable margins of tumor removal. Approximately 2 months after surgery, the ferret received a course of radiation therapy and is currently being monitored for tumor regrowth.

**Descriptors:** ferret, squamous cell carcinoma, radiation therapy, rostral maxillectomy.

Greenacre, C.B. (2003). **Fungal diseases of ferrets.** *Veterinary Clinics of North America. Exotic Animal Practice* 6(2): 435-448, Viii. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Although fungal disease in ferrets is uncommon, a few cases have been documented, demonstrating that it should be on the clinician's rule out list, especially if the patient has a long-term illness that is not responding appropriately to antibiotics, as was the clinical presentation in many of these documented cases.

**Descriptors:** ferrets, mycoses, diagnosis, drug therapy, prognosis, fungal diseases.

Greenacre, C.B. (2003). **Incidence of adverse events in ferrets vaccinated with distemper or rabies vaccine: 143 cases (1995-2001).** *Journal of the American Veterinary Medical Association* 223(5): 663-665. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** **OBJECTIVE:** To determine the incidence of adverse events in ferrets vaccinated with a modified-live avian cell culture canine distemper virus vaccine licensed for use in ferrets, an inactivated rabies vaccine licensed for use in ferrets, or both. **DESIGN:** Retrospective study. **ANIMALS:** 143 ferrets. **PROCEDURE:** Medical records were reviewed to identify ferrets that had an adverse event after vaccination. **RESULTS:** Adverse events developed within 25 minutes after vaccination in 13 ferrets. One ferret developed an adverse event after receiving a distemper and a rabies vaccine simultaneously and developed a second adverse event the following year after receiving the rabies vaccine alone. Therefore, a total of 14 adverse events were identified. All adverse events were an anaphylactic reaction characterized by generalized hyperemia, hypersalivation, and vomiting. Ten of the 14 anaphylactic reactions occurred after ferrets received both vaccines, 3 occurred after ferrets received the distemper vaccine alone, and 1 occurred after a ferret received the rabies vaccine alone. Incidences of adverse events after administration of both vaccines, the distemper vaccine alone, and the rabies vaccine alone were 5.6, 5.9, and 5.6%, respectively. Ferrets that had an anaphylactic reaction were significantly older at the time of vaccination than were ferrets that did not. **CONCLUSIONS AND CLINICAL RELEVANCE:** Results suggest that there may be a high incidence of anaphylactic reactions after vaccination of domestic ferrets. Ferrets should be observed for at least 25 minutes after vaccination, and veterinarians who vaccinate ferrets should be prepared to treat anaphylactic reactions.

**Descriptors:** ferrets, distemper virus, canine immunology, rabies vaccines, adverse effects of viral vaccines, age factors, anaphylaxis, incidence of rabies virus, retrospective studies, risk factors.

**Notes:** Comments: Comment In: J Am Vet Med Assoc. 2003 Oct 15;223(8):1112; author reply 1112.

Hanley, C. S, P. MacWilliams, S. Giles, and J. Pare (2006). **Diagnosis and successful treatment of *Cryptococcus neoformans* variety grubii in a domestic ferret.** *Canadian Veterinary Journal* 47(10): 1015-1017. ISSN: 0008-5286.

**NAL Call Number:** 41.8 R3224

**Abstract:** A domestic ferret was presented for episodic regurgitation. Cytologic examination and culture of an enlarged submandibular lymph node revealed *Cryptococcus neoformans* variety grubii (serotype A). The ferret was successfully treated with itraconazole. This is the first documented case of *Cryptococcus neoformans* variety grubii in a ferret in the United States.

**Descriptors:** ferret, *Cryptococcus neoformans*, diagnosis, treatment.

Harms, C.A., K.K. Sladky, W.A. Horne, and M.K. Stoskopf (2002). **Epidural analgesia in ferrets.** *Exotic DVM* 4(3): 40-42. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, anesthesia, epidural, analgesia, morphine, pharmacodynamics.

**Notes:** 4th Annual international conference on exotics (ICE2002), Key West, Florida, USA, 2002.

Hermann, B. A, K. Plensdorf L, and D. Degner A (2006). **Medical and surgical management of traumatic elbow luxation in a juvenile ferret.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 651-655. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Elbow luxation is a common orthopedic injury in the ferret. The injury is usually caused by trauma but can also occur spontaneously. The most successful treatment involves a combination of surgical and medical

intervention. Surgical treatment includes open reduction of the elbow joint and stabilization with orthopedic implants. Medical treatment includes external coaptation, analgesia, and prevention of infection. Owner compliance also plays an important role in return to full function of the luxated ferret elbow joint.

**Descriptors:** ferret, elbow luxation, traumatic, management, medical, surgical, orthopedic implants.

Hess, L. (2006). **Clinical techniques in ferrets.** In: *Small animal and exotics: Proceedings of the North American Veterinary Conference. January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1722-1723.

**Online:** <http://www.tnavc.org>

**Descriptors:** ferrets, blood sampling, clinical techniques, restraint techniques, handling, treatment.

Hoefler, H. (2006). **Practice tips in ferrets.** In: *Small animal and exotics: Proceedings of the North American Veterinary Conference., January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1731.

**Online:** <http://www.tnavc.org>

**Descriptors:** ferrets, handling, blood sampling, catheterization, restraint, methods.

Hoefler, H.L. (2004). **Clinical techniques in ferrets.** In: *Small animal and exotics Book two: Pain management zoonosis Proceedings of the North American Veterinary Conference., January 17, 2004-January 21, 2004, Orlando, Florida, USA.*, Eastern States Veterinary Association: Gainesville, USA, Vol. 18, p. 1385-1387.

**Descriptors:** ferrets, blood chemistry, blood sampling, transfusion, treatment, clinical examination, drug therapy, fluid therapy, hematology, restraint.

Huber, V.C. and J.A. McCullers (2006). **Live attenuated influenza vaccine is safe and immunogenic in immunocompromised ferrets.** *Journal of Infectious Diseases* 193(5): 677-684. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** Patients undergoing chemotherapy for cancer are highly susceptible to influenza virus infection. Prevention of influenza virus infection is complicated in the immunocompromised host because of suboptimal responses to the trivalent inactivated influenza vaccine (TIV). A new, live attenuated influenza vaccine (LAIV; FluMist) may offer a more effective alternative to TIV, but the safety of this LAIV in immunocompromised patients must first be established. In the present study, FluMist was administered to ferrets immunocompromised by treatment with dexamethasone and cytarabine. Ferrets exhibited no signs or symptoms attributable to FluMist, and nasal clearance of LAIV strains from immunocompromised ferrets was similar to that from control ferrets. Serum antibody responses against the vaccinating strains were analyzed as a measure of vaccine efficacy. Antibody titers to all 3 vaccine strains in immunocompromised ferrets were similar to those seen in mock-treated control ferrets, as assessed by microneutralization assay. These findings support the potential use of this vaccine in immunocompromised humans.

**Descriptors:** ferrets, blood antibodies, immunocompromised host, influenza A virus, influenza B virus, influenza vaccines, cytarabine, dexamethasone, immunosuppressive agents.

Iwata, K., Y. Kuwahara, and N. Kuwahara (2002). **Two cases of hyperadrenocorticism in ferrets.** *Journal of the Japan Veterinary Medical Association* 55(3): 163-165. ISSN: 0446-6454.

**Abstract:** Because of high serum levels of 17alpha-hydroxyprogesterone, two ferrets with bilateral symmetrical alopecia of the trunk were tentatively diagnosed as having hyperadrenocorticism. Abdominal computed tomography revealed no obvious adrenal enlargement in either animal. In case 1, treatment with danazol followed by cyproterone acetate produced no fur recovery. Histopathological examinations revealed adrenocortical carcinoma in both animals. In about a month and a half after tumid left adrenal resection, both ferrets' fur had completely recovered. The animals continue in good condition at the present. In case 1, serum 17alpha-hydroxyprogesterone has dropped to the normal range.

**Descriptors:** ferrets, adrenal glands, endocrine diseases, animal glands, endocrine glands, Mustelidae.

**Language of Text:** Japanese.

Jekl, V., K. Hauptman, E. Jeklova, G. Dorrestein M, and Z. Knotek (2006). **Hydrometra in a ferret-case report.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 695-700. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** A desexed female ferret was presented with bilateral alopecic changes. Clinical examination revealed generalized alopecia and abdominal distension. A polycystic mass was found behind the right kidney, and the whole abdomen was filled with a large turgid mass. Radiography and ultrasonography confirmed the presumptive diagnosis of a hydrometra. Hematology and serum biochemistry showed regenerative anemia with light azotemia. Laparotomy showed the presence of a neoplastic mass at the location of the right ovary, a massive enlargement of the uterus filled with a clear fluid, and a subcapsular cyst on the left kidney. After surgery, histopathologic examination of the tissues diagnosed a leiomyoma of the right ovary with hyperplasia of the uterine wall.

**Descriptors:** ferret, hydrometria, case report, alopecic changes, polycystic mass, kidney, diagnosis, surgery.

Johnson, D. (2002). **Clinical use of cryosurgery for ferret adrenal gland removal.** *Exotic DVM* 4(3): 71-73. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferret, adrenal gland diseases, cryosurgery, adrenalectomy, neoplasms, surgical operations.

**Notes:** 4th Annual international conference on exotics (ICE2002), Key West, Florida, USA, 2002.

Johnson Delaney, C.A. (2005). **The ferret gastrointestinal tract and *Helicobacter mustelae* infection.** *Veterinary Clinics of North America. Exotic Animal Practice* 8(2): 197-212. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Descriptors:** ferrets, microbiology, gastrointestinal tract, helicobacter infections, *Helicobacter mustelae* pathogenicity, biliary tract, disease models, pancreas, exocrine physiology.

Johnson Delaney, C.A. (2005). **Ferret cardiopulmonary resuscitation.** *Seminars in Avian and Exotic Pet Medicine* 14(2): 135-142. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, cardiopulmonary resuscitation, therapy, heart diseases, reviews, techniques, cardiac massage, cardiac arrest.

Johnson Delaney, C.A. (2005). **Presurgical and surgical support of ferrets.** *Exotic DVM* 6(6): 25-28. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, support, surgical, presurgical, anesthetics, dosage, drug therapy, fluid therapy, preoperative care.

Johnson Delaney, C.A. (2004). **Medical therapies for ferret adrenal disease.** *Seminars in Avian and Exotic Pet Medicine* 13(1): 3-7. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, adrenal gland diseases, adrenalectomy, medical therapies, surgical operations, neoplasia, symptoms.

Johnston, M.S. (2005). **Clinical approaches to analgesia in ferrets and rabbits.** *Seminars in Avian and Exotic Pet Medicine* 14(4): 229-235. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, rabbits, analgesia, behavior, ketamine, local anesthetics, non steroidal anti-inflammatory agents, opioids, pain management.

Kawaguchi, H., N. Miyoshi, M. Souda, H. Maeda, H. Kawashima, K. Gejima, K. Uchida, Y. Umekita, and H. Yoshida (2006). **Renal Adenocarcinoma in a Ferret.** *Veterinary Pathology* 43(3): 353-356. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** A spontaneous case of renal tumor was observed in a 7-year-old ovariectomized female pet ferret (*Mustela putorius furo*). Clinical signs included exhaustion, emaciation, anorexia, and stooping position. At necropsy, a solid and cystic mass replaced the left kidney and adrenal gland. The tumor was composed of pleomorphic epithelial cells with a large number of giant cells. Metastases were recognized in the lung, liver,

greater omentum, right renal pelvis, and systemic lymph nodes. Immunohistochemical stains revealed that the tumor cells were positive for CD10, cytokeratin (CAM 5.2), and Ki-67 (MIB-1). On the basis of morphologic and immunohistochemical features, the tumor was diagnosed as a pleomorphic renal adenocarcinoma. This type of neoplasm is very rare in all species and has never been reported in a ferret.

**Descriptors:** *Mustela putorius*, case studies, kidney diseases, adenocarcinoma, metastasis, histopathology.

Kona Boun, J.J., B. Mercier, E. Troncy, J. Pare, and I. Langlois (2004). **Le furet domestique. [The domestic ferret].** *Medecin Veterinaire Du Quebec* 34(3): 220-227.

**Descriptors:** ferrets, anesthetic techniques, handling, venous access, catheterization, intubation, analgesics, anesthetics, fluid administration.

**Language of Text:** French.

Kottwitz, J. (2004). **Horizontal beam radiography in ferrets.** *Exotic DVM* 6(1): 37-41. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, horizontal beam radiography, diagnostic techniques, restraint.

Lennox, A.M. (2005). **Gastrointestinal diseases of the ferret.** *Veterinary Clinics of North America. Exotic Animal Practice* 8(2): 213-225. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Descriptors:** ferrets, gastrointestinal diseases, age factors, diagnosis, differential, foreign bodies, complications, etiology.

Lester, S.J., N.J. Kowalewich, K.H. Bartlett, M.B. Krockenberger, T.M. Fairfax, and R. Malik (2004).

**Clinicopathologic features of an unusual outbreak of cryptococcosis in dogs, cats, ferrets, and a bird: 38 cases (January to July 2003).** *Journal of the American Veterinary Medical Association* 225(11): 1716-1722. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** OBJECTIVE: To determine clinical and pathologic findings associated with an outbreak of cryptococcosis in an unusual geographic location (British Columbia, Canada). DESIGN: Retrospective study. ANIMALS: 1 pink-fronted cockatoo, 2 ferrets, 20 cats, and 15 dogs. PROCEDURE: A presumptive diagnosis of cryptococcosis was made on the basis of serologic, histopathologic, or cytologic findings, and a definitive diagnosis was made on the basis of culture or immunohistochemical staining. RESULTS: No breed or sex predilections were detected in affected dogs or cats. Eleven cats had neurologic signs, 7 had skin lesions, and 5 had respiratory tract signs. None of 17 cats tested serologically for FeLV yielded positive results; 1 of 17 cats yielded positive results for FIV (western blot). Nine of 15 dogs had neurologic signs, 2 had periorbital swellings, and only 3 had respiratory tract signs initially. Microbiologic culture in 15 cases yielded 2 isolates of *Cryptococcus neoformans* var *grubii* (serotype A) and 13 isolates of *C. neoformans* var *gattii* (serotype B); all organisms were susceptible to amphotericin B and ketoconazole. Serologic testing had sensitivity of 92% and specificity of 98%. CONCLUSIONS AND CLINICAL RELEVANCE: Serologic titers were beneficial in identifying infection in animals with nonspecific signs, but routine serum biochemical or hematologic parameters were of little value in diagnosis. Most animals had nonspecific CNS signs and represented a diagnostic challenge. Animals that travel to or live in this region and have nonspecific malaise or unusual neurologic signs should be evaluated for cryptococcosis.

**Descriptors:** ferrets, dogs, cats, birds, epidemiology, diseases, cockatoos, cryptosporidiosis, amphotericin b, antifungal agents, bird diseases, drug therapy, cat diseases, cryptosporidiosis, disease outbreaks, dog diseases, ketoconazole, retrospective studies, treatment outcomes.

Lichtenberger, M. (2005). **Shock, fluid therapy, anesthesia and analgesia in the ferret.** *Exotic DVM* 7(2): 24-30. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, anesthesia, analgesia, hypovolemic shock, corrective fluid therapy, circulatory diseases.

**Notes:** International Conference on Exotics, Ft. Lauderdale, Florida, USA. May 26-28, 2005.

Lindeberg, H., J. Aalto, S. Amstislavsky, K. Piltti, M. Jarvinen, and M. Valtonen (2003). **Surgical recovery and**

**successful surgical transfer of conventionally frozen-thawed embryos in the farmed European polecat (*Mustela putorius*).** *Theriogenology* 60(8): 1515-1525. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Abstract:** Surgical transfer of in vivo produced conventionally frozen-thawed embryos of farmed European polecat (*Mustela putorius*) was investigated as a part of an ex-situ preservation program which has the long-term aim of developing a genome resource bank for the endangered European mink (*Mustela lutreola*). Eighteen oestrous yearling European polecat donors were mated once daily on two consecutive days using 13 fertile males. The donors were surgically flushed for embryos 8-9 days after the first mating. The embryo recovery rate was 60% (116 embryos/193 corpora lutea). The embryos were cryopreserved with 1.5 M ethylene glycol in a programmable freezer using a conventional slow freezing protocol. The thawed embryos were surgically transferred either after dilution with 0.5 M sucrose or directly without removal of ethylene glycol. To induce ovulation, eight recipient females were mated once daily on two consecutive days with vasectomized males starting 7 or 8 days before embryo transfer. The recipients received 7-11 embryos each and three recipients delivered a total of nine pups after a gestation length of 44-46 days. The embryo survival rate was 10% (9 pups/93 frozen embryos). This report describes the first successful cryopreservation of embryos in the Mustelidae family resulting in viable offspring. The low embryo survival rate, however, indicates that the freezing-thawing protocol needs to be improved.

**Descriptors:** ferrets, embryo transfer, tissue and organ harvesting, breeding, cryopreservation, ethylene glycol, gestational age, litter size, ovulation induction, uterus surgery.

Lindeberg, H., S. Amstislavsky, M. Jarvinen, J. Aalto, and M. Valtonen (2002). **Surgical transfer of in vivo produced farmed European polecat (*Mustela putorius*) embryos.** *Theriogenology* 57(9): 2167-2177. ISSN: 0093-691X.

**NAL Call Number:** QP251.A1T5

**Abstract:** Surgical embryo transfer of farmed European polecat (*Mustela putorius*) was investigated as part of an ex situ preservation project. The long-term objective of the project is to develop effective technology for ex situ conservation of the European mink (*Mustela lutreola*), which is a highly endangered aboriginal European species. Twenty European polecat females, which served as a model species for the European mink, were humanely killed 4-9 days after first mating and embryos were recovered from oviducts and uteri. Donor-recipient pairs (n = 16) were generated by mating the donors (n = 20) once a day for 2 consecutive days with fertile males and by mating the corresponding recipients (n = 16) on the same days with vasectomized males. An embryo recovery rate of 70% (200 recovered embryos/284 corpora lutea) was achieved from 20 donors. Morulae and blastocysts were recovered between Days 5 and 9 after first mating and were regarded as the best developmental stages for uterine embryo transfer. A total of 172 embryos were transferred surgically under general anaesthesia into the ovarian third of the left uterine horn of 16 recipients with a thin glass capillary. Eleven recipients (69%) produced 72 pups equivalent to an average success rate of 42% (72 pups/172 transferred embryos). The average litter size was 4.5 (range 0-9). These results with this model species, farmed European polecat, demonstrate the potential of embryo transfer as an effective method for the preservation of the endangered European mink (*M. lutreola*). These species are closely related and have a similar reproductive physiology. However, success of applying embryo transfer in conserving European mink is still dependent on further studies both into its reproductive physiology and developing of improved flushing techniques for anaesthetized donors and the successful transfer of frozen-thawed embryos.

**Descriptors:** Mustela, embryo transfer, surgery, endangered species, wildlife management, animal models, morula, blastocyst, embryogenesis, ovulation.

Lloyd, M. (2002). **Veterinary care of ferrets. 2. Common clinical conditions.** *In Practice* 24(3): 136-138, 141, 144-145. ISSN: 0263-841X.

**NAL Call Number:** SF601.I4

**Descriptors:** ferrets, viral diseases, bacterial diseases, parasitoses, distemper virus, gastroduodenal diseases, otodectes cynotis, cardiomyopathy, nutritional disorders, paresis, ataxia, diagnosis, medical treatment, *Helicobacter mustelae*, hyperoestrogenism.

Lloyd, M. (2002). **Veterinary care of ferrets. 1. Clinical examination and routine procedures.** *In Practice* 24(2): 90-95. ISSN: 0263-841X.

**NAL Call Number:** SF601.I4

**Descriptors:** ferrets, veterinary medicine, clinical examination, radiography, blood sampling, urine analysis, vaccination, disease prevention, anesthesia, surgical operations, postoperative care.

Lu, D., C.R. Lamb, J.C. Patterson Kane, and R. Cappello (2004). **Treatment of a prolapsed lumbar intervertebral disc in a ferret.** *Journal of Small Animal Practice* 45(10): 501-503. ISSN: 0022-4510.

**Abstract:** A seven-month-old, male ferret had acute paraplegia and radiographs showed signs of disc prolapse between the second and third lumbar vertebrae (L2/3). Hemilaminectomy was performed to decompress the spinal cord. Histological examination revealed that the extradural material was consistent with annulus fibrosus and the L2/3 articular facets were enlarged as a result of bone remodelling. The ferret became ambulatory one month postoperatively. Five months postoperatively, the ferret had normal posture with mild proprioceptive deficits in the pelvic limbs, and fusion of the L2 and L3 vertebral bodies.

**Descriptors:** ferrets, intervertebral disk displacement, lumbar vertebrae surgery, laminectomy methods, spinal cord compression, surgery, disc prolapse, lumbar, treatment outcome.

Lunn, J.A., P. Martin, S. Zaki, and R. Malik (2005). **Pneumonia due to *Mycobacterium abscessus* in two domestic ferrets (*Mustelo putorius furo*).** *Australian Veterinary Journal* 83(9): 542-546. ISSN: 0005-0423.

**NAL Call Number:** 41.8 Au72

**Abstract:** Two ferrets were diagnosed with pneumonia due to *Mycobacterium abscessus*. Both cases were treated successfully using clarithromycin after positive cultures were obtained via unguided bronchoalveolar lavage. This is the first time *M abscessus* has been isolated in our laboratory and the first report of this organism causing disease in companion animals in Australia. Underlying respiratory tract disease was thought to be an important factor in the development of the infections. Thorough investigation of chronic lower respiratory tract disease in ferrets is recommended as this species appears predisposed to atypical infections.

**Descriptors:** ferrets, anti-bacterial agents, mycobacterium infections, bacterial pneumonia, bronchoalveolar lavage, fluid microbiology, mycobacterium isolation, treatment outcome.

Mayer, J. (2006). **Management of ferrets with multiple pathologies.** In: *Small animal and exotics Proceedings of the North American Veterinary Conference. January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1750.

**Online:** <http://www.tnavc.org>

**Descriptors:** ferrets, diseases, concurrent infections, multiple pathologies, management, drug therapy.

Mayer, J. (2006). **Diagnostic work-up of the anemic ferret.** In: *Small animal and exotics: Proceedings of the North American Veterinary Conference. January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1746-1747.

**Online:** <http://www.tnavc.org>

**Descriptors:** ferret, anemia, diagnostic techniques, hematocrit, neoplasms, treatment, Helicobacter.

Mayer, J. (2006). **Interpreting renal values in the ferret.** In: *Small animal and exotics: Proceedings of the North American Veterinary Conference., January 7, 2006-January 11, 2006, Orlando, Florida, USA.*, The North American Veterinary Conference: Gainesville, USA, Vol. 20, p. 1743.

**Online:** <http://www.tnavc.org>

**Descriptors:** ferret, renal values, interpreting, blood chemistry, diagnostic techniques, kidney diseases, normal values.

McLain, D.E. (2006). **Use of an adjustable restraint device for prolonged and intermittent intravenous infusion and blood sampling in ferrets.** *Lab Animal* 35(7): 47-50. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Descriptors:** ferrets, restraint, instrumentation, blood specimen, collection, methods, infusions, intravenous, methods, infusions.

Miller, D.S., R.P. Eagle, S. Zabel, R. Rosychuk, and T.W. Campbell (2006). **Efficacy and safety of selamectin in the treatment of *Otodectes cynotis* infestation in domestic ferrets.** *Veterinary Record* 159(22): 748. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Descriptors:** ferrets, Otodectes, infestation, treatment, efficacy, safety, selamectin.

Montiani Ferreira, F., B.C. Mattos, and H.H.A. Russ (2006). **Reference values for selected ophthalmic diagnostic tests of the ferret (*Mustela putorius furo*).** *Veterinary Ophthalmology* 9(4): 209-213. ISSN: 1463-5216.

**NAL Call Number:** SF891.V47

**Abstract:** To perform selected ophthalmic diagnostic tests in healthy ferrets with the aim of establishing normal physiological reference values for this species. A total of 15 healthy, unrelated ferrets were used to test most of the parameters in this investigation. Eight of the 15 ferrets were used for central corneal thickness evaluation. Ages varied from 1.5 to 6 years of age. Selected diagnostic ocular tests were performed including Schirmer tear test, tonometry using an applanation tonometer (Tonopen<sup>®</sup>), central corneal thickness using an ultrasonic pachymeter (Sonomed, Micropach<sup>®</sup>, Model 200P+) and culture of the normal conjunctival bacterial flora. *Staphylococcus* sp. and *Corynebacterium* sp. were isolated from healthy conjunctival and eyelid margins, suggesting they are normal constituents of the conjunctival flora of the ferret. Results for selected ocular diagnostic tests investigated here for the ferret eye were as follows: intraocular pressure: 14.50 ± 3.27 mmHg; Schirmer tear test: 5.31 ± 1.32 mm/min; central corneal thickness: 0.337 ± 0.020 mm. No statistically significant differences between ages or genders were found for any of the results. The reference data for the ocular tests obtained in this investigation will help veterinary ophthalmologists to more accurately diagnose ocular diseases in the ferret. Knowledge of these reference values will be particularly useful to diagnose discrete or unusual pathological changes of the ferret eye.

**Descriptors:** ferret, reference values, ophthalmic diagnostic tests, normal physiological reference values, ferret eye, diagnosis, ocular diseases.

Moore, G.E., N.W. Glickman, M.P. Ward, K.S. Engler, H.B. Lewis, and L.T. Glickman (2005). **Incidence of and risk factors for adverse events associated with distemper and rabies vaccine administration in ferrets.** *Journal of the American Veterinary Medical Association* 226(6): 909-912. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** **OBJECTIVE:** To determine incidence of and risk factors for adverse events associated with distemper and rabies vaccine administration in ferrets. **DESIGN:** Retrospective cohort study. **ANIMALS:** 3,587 ferrets that received a rabies or distemper vaccine between January 1, 2002, and December 31, 2003. **PROCEDURES:** Electronic medical records were searched for possible vaccine-associated adverse events. Adverse events were classified by attending veterinarians as nonspecific vaccine reactions, allergic reactions, or anaphylaxis. Patient information that was collected included age, weight, sex, cumulative number of distemper and rabies vaccinations received, clinical signs, and treatment. The association between potential risk factors and occurrence of an adverse event was estimated with logistic regression. **RESULTS:** 30 adverse events were recorded. The adverse event incidence rates for administration of rabies vaccine alone, distemper vaccine alone, and rabies and distemper vaccines together were 0.51%, 1.00%, and 0.85%, respectively. These rates were not significantly different. All adverse events occurred immediately following vaccine administration and most commonly consisted of vomiting and diarrhea (52%) or vomiting alone (31%). Age, sex, and body weight were not significantly associated with occurrence of adverse events, but adverse event incidence rate increased as the cumulative number of distemper or rabies vaccinations received increased. In multivariate logistic regression analysis, only the cumulative number of distemper vaccinations received was significantly associated with the occurrence of an adverse event. **CONCLUSIONS AND CLINICAL RELEVANCE:** Results suggest that in ferrets, the risk of vaccine-associated adverse events was primarily associated with an increase in the number of distemper vaccinations.

**Descriptors:** diarrhea, ferrets, rabies vaccines, adverse effects of viral vaccines, distemper virus, canine immunology, logistic models, rabies virus, vomiting.

Morera, N., X. Valls, and J. Mascort (2006). **Intervertebral disk prolapse in a ferret.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 667-671. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** This case report describes the diagnosis and resolution of an inter-vertebral disk prolapse in a 6-year-old ferret. No predisposing causes were found in the patient's history. A right hemilaminectomy, performed 1 week after presentation, was chosen to treat the patient surgically, and complete remission of clinical signs was

achieved 2 months after presentation.

**Descriptors:** ferret, intervertebral disk prolapse, hemilaminectomy, remission, clinical signs.

Munday, J.S., N.L. Stedman, and L.J. Richey (2003). **Histology and immunohistochemistry of seven ferret vaccination-site fibrosarcomas.** *Veterinary Pathology* 40(3): 288-293. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** The anatomical location, histology, and immunohistochemistry of 10 ferret dermal and subcutaneous fibrosarcomas were examined. Seven of the 10 tumors were from locations used for vaccination. All fibrosarcomas contained spindle-shaped cells surrounded by variable quantities of connective tissue stroma. However, vaccination-site fibrosarcomas (VSFs) subjectively contained a higher degree of cellular pleomorphism. Multinucleated cells were present in three of seven VSFs but not in any of the nonvaccination-site fibrosarcomas (NVSFs). Large histiocytic cells, interpreted as macrophages, containing intracytoplasmic basophilic granular material were observed in two VSFs but not in any of the NVSFs. Five VSFs contained peripheral lymphoplasmacytic aggregates. Immunohistochemically, three VSFs stained with anti-smooth muscle actin antibodies and one stained with antibodies against desmin. No expression of muscle cytoskeletal filaments was observed in any NVSF. Filaments interpreted as actin were visible in both the VSFs examined ultrastructurally. One of the VSFs examined ultrastructurally contained intracytoplasmic crystalline material. The preferential development of subcutaneous fibrosarcomas in vaccination sites suggests that, as in cats, vaccination may promote local sarcoma development in ferrets. Additionally, some of the histologic, immunohistochemical, and ultrastructural features of these tumors are similar to those reported for feline vaccine-associated sarcomas. To the authors' knowledge, vaccination has not previously been reported to be oncogenic in any species other than cats.

**Descriptors:** ferrets, fibrosarcoma, soft tissue neoplasms, vaccination adverse effects, fibrosarcoma etiology, pathology, ultrastructure, immunohistochemistry, retrospective studies, etiology.

Murray, M.J. (2002). **Laparoscopy in the domestic ferret.** *Exotic DVM* 4(3): 65-69. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferret, laparoscopy, surgery, anesthesia, diagnostic techniques, equipment.

**Notes:** 4th Annual international conference on exotics (ICE2002), Key West, Florida, USA, 2002.

Mutlow, A. and D.S. Biller (2004). **A ferret with a painful abdomen.** *Exotic DVM* 99(3): 230, 232, 234. ISSN: 8750-7943.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferret, painful abdomen, disease, diagnosis, veterinary.

Nolte, D.M., C.A. Carberry, K.M. Gannon, and F.C. Boren (2002). **Temporary tube cystostomy as a treatment for urinary obstruction secondary to adrenal disease in four ferrets.** *The Journal of the American Animal Hospital Association* 38(6): 527-532. ISSN: 0587-2871.

**NAL Call Number:** SF601.A5

**Descriptors:** ferrets, pets, age, adrenal gland diseases, clinical aspects, urethra, urination disorders, complications, adrenalectomy, surgery, catheterization, catheters, prostate, histopathology, pancreas, omentum, adenoma, adenocarcinoma, adrenal cortex, postoperative care, urination, small animal practice, animal hospitals.

Nugent, J.S., B. Whisman, and L.L. Hagan (2003). **Ferret allergy: Identification of serum specific ige to albumin with crossreactivity to cat.** *Journal of Allergy and Clinical Immunology* 111(2 Abstract Supplement): S324. ISSN: 0091-6749.

**Descriptors:** ferret, allergy, immune system disease, serum specific ige, albumin, electrophoretic techniques, cats.

**Notes:** AAAAI 60th Anniversary Meeting, Denver, CO, USA; March 7-12, 2003.

Oglesbee, B.L. (2006). *The 5-Minute Veterinary Consult: Ferret and Rabbit.*, 1st edition, Blackwell Publishing: Ames, Iowa, 422 p. ISBN: 0781793998.

**NAL Call Number:** SF997.5.F47 O35 2006

**Descriptors:** ferrets, rabbits, diseases, handbooks, veterinary medicine.

Orcutt, C.J. (2003). **Ferret urogenital diseases.** *Veterinary Clinics of North America. Exotic Animal Practice* 6(1): 113-138. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Improved nutrition and client education have decreased the incidence of certain urinary tract diseases in ferrets. Early neutering programs at commercial breeding farms in the United States have also led to a marked decrease in the incidence of reproductive tract disease, especially estrogen-induced bone marrow suppression. However, the increased incidence of adrenal disease and its secondary effects on reproductive and associated urinary tract tissue presents an ongoing challenge for the clinician working with pet ferrets. Acute and chronic renal failure remain important, though less common, disease entities. It is imperative that the veterinarian working with pet ferrets be aware of the clinical presentation and clinicopathologic abnormalities associated with these syndromes.

**Descriptors:** ferrets, urogenital diseases, diagnosis, surgery, therapy, ultrasonography, nutrition, neutering, reproductive tract disease.

Patterson, M.M., A.B. Rogers, M.D. Schrenzel, R.P. Marini, and J.G. Fox (2003). **Alopecia attributed to neoplastic ovarian tissue in two ferrets.** *Comparative Medicine* 53(2): 213-217. ISSN: 1532-0820.

**NAL Call Number:** SF77 .C65

**Abstract:** Ferrets with adrenal gland dysfunction have alopecia as their most common clinical sign of disease. Two cases of alopecia in neutered female ferrets are reported that were associated instead with neoplastic tissue found at the site of an ovarian pedicle. Androstenedione and 17-hydroxyprogesterone, but not estradiol, concentrations were high in both ferrets. Following surgical resection of the abnormal tissue in one ferret, the high hormone values decreased quickly and hair regrowth ensued. In both cases, histologic examination revealed features consistent with classical sex cord-stromal (gonadostromal) tumors: prominent spindle cells, along with polyhedral epithelial cells and cells with vacuolated cytoplasm. Although similar cell types have been described in the adrenal glands of ferrets with adrenal-associated endocrinopathy, an ovarian origin for the current neoplasms is considered likely on the basis of their anatomic location; accessory adrenal tissue has only been described close to an adrenal gland or in the cranial perirenal fat of ferrets. Immunohistochemical analysis, using an antibody against Mullerian-inhibiting substance, failed to prove definitively the source of the steroidogenic cells.

**Descriptors:** ferrets, alopecia, adrenal gland diseases, ovarian cancer, estradiol, progesterone, androstenedione, immunohistochemistry, excision of the ovaries.

Peltola, V.T., K.L. Boyd, J.L. McAuley, J.E. Rehg, and J.A. McCullers (2006). **Bacterial sinusitis and otitis media following influenza virus infection in ferrets.** *Infection and Immunity* 74(5): 2562-2567. ISSN: 1098-5522.

**NAL Call Number:** QR1.I57

**Abstract:** *Streptococcus pneumoniae* is the leading cause of otitis media, sinusitis, and pneumonia. Many of these infections result from antecedent influenza virus infections. In this study we sought to determine whether the frequency and character of secondary pneumococcal infections differed depending on the strain of influenza virus that preceded bacterial challenge. In young ferrets infected with influenza virus and then challenged with pneumococcus, influenza viruses of any subtype increased bacterial colonization of the nasopharynx. Nine out of 10 ferrets infected with H3N2 subtype influenza A viruses developed either sinusitis or otitis media, while only 1 out of 11 ferrets infected with either an H1N1 influenza A virus or an influenza B virus did so. These data may partially explain why bacterial complication rates are higher during seasons when H3N2 viruses predominate. This animal model will be useful for further study of the mechanisms that underlie viral-bacterial synergism.

**Descriptors:** ferrets, bacterial infection, virus infection, sinusitis, pneumonia, viral-bacterial synergism.

Pennick, K.E., M.A. Stevenson, K.S. Latimer, B.W. Ritchie, and C.R. Gregory (2005). **Persistent viral shedding during asymptomatic Aleutian mink disease parvoviral infection in a ferret.** *Journal of Veterinary Diagnostic Investigation* 17(6): 594-597. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** A 2-year-old domestic ferret that appeared clinically healthy was repeatedly seropositive for Aleutian

mink disease parvovirus (ADV) over a 2-year observation period. Antibody titers, determined by counter-immunoelectrophoresis, ranged from 1024 to 4096. Viral DNA also was identified in serum, urine, feces, and blood cell fractions by polymerase chain reaction analysis. Ultimately, DNA in situ hybridization revealed ADV DNA in histologic sections of various tissues and organs. These data indicate that this asymptomatic ferret was persistently infected with ADV.

**Descriptors:** ferrets, Aleutian mink disease, virology, carrier state, virus shedding, antibodies, blood, physiopathology, DNA, physiology, kidney, liver, lung, spleen, urine.

Peterson, R.A., M. Kiupel, M. Bielinska, S. Kiiveri, M. Heikinheimo, C.C. Capen, and D.B. Wilson (2004).

**Transcription factor GATA-4 is a marker of anaplasia in adrenocortical neoplasms of the domestic ferret (*Mustela putorius furo*).** *Veterinary Pathology* 41(4): 446-449. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** Adrenocortical neoplasms are a common cause of morbidity in neutered ferrets. Recently we showed that gonadectomized DBA/2J mice develop adrenocortical tumors that express transcription factor GATA-4. Therefore, we screened archival specimens of adrenocortical neoplasms from neutered ferrets to determine whether GATA-4 could be used as a tumor marker in this species. Nuclear immunoreactivity for GATA-4 was evident in 19/22 (86%) of ferret adrenocortical carcinomas and was prominent in areas exhibiting myxoid differentiation. Normal adrenocortical cells lacked GATA-4 expression. Two other markers of adrenocortical tumors in gonadectomized mice, inhibin-alpha and luteinizing hormone receptor, were coexpressed with GATA-4 in some of the ferret tumors. No GATA-4 expression was observed in three cases of nodular hyperplasia, but patches of anaplastic cells expressing GATA-4 were evident in 7/14 (50%) of tumors classified as adenomas. We conclude that GATA-4 can function as a marker of anaplasia in ferret adrenocortical tumors.

**Descriptors:** ferrets, adrenal cortex neoplasms, adrenocortical carcinoma, DNA binding, proteins metabolism, transcription factors, tumor markers, biological metabolism.

Peterson, R.A. II, M. Kiupel, M. Bielinska, S. Kiiveri, M. Heikinheimo, C.C. Capen, and D.B. Wilson (2004).

**Transcription factor GATA-4 is a marker of anaplasia in adrenocortical neoplasms of the domestic ferret (*Mustela putorius furo*).** *Veterinary Pathology* 41(4): 446-449. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Descriptors:** ferret, adrenocortical neoplasms, transcription factor GATA-4, disease marker, anaplasia.

Pilny, A.A. and S. Chen (2004). **Ferret insulinoma: Diagnosis and treatment.** *Compendium on Continuing Education for the Practicing Veterinarian* 26(9): 722-728. ISSN: 0193-1903.

**NAL Call Number:** SF601.C66

**Descriptors:** ferret, insulinoma, diagnosis, treatment, neoplasia.

Pilny, A.A. and L. Hess (2004). **Ferrets: Wound healing and therapy.** *Veterinary Clinics of North America. Exotic Animal Practice* 7(1): 105-121. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** In all species of mammals, the stages of wound healing are the same, and both host factors and wound characteristics affect how wounds heal. The basic principles of wound care in ferrets, such as lavage, bandaging, and surgical closure, are similar to those in other species; however, knowledge of ferrets' anatomy and pathophysiology, as well as skin conditions commonly seen in ferrets, will help ensure proper wound healing.

**Descriptors:** ferrets, injuries, wounds, wound healing, therapy, lavage, bandaging, anatomy, pathophysiology, skin conditions.

Ramer, J.C., K.G. Benson, J.K. Morrisey, R.T. O'brien, and J. Paul Murphy (2006). **Effects of melatonin administration on the clinical course of adrenocortical disease in domestic ferrets.** *Journal of the American Veterinary Medical Association* 229(11): 1743-1748. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** Objective-To evaluate the effect of oral administration of melatonin on clinical signs, tumor size, and serum steroid hormone concentrations in ferrets with adrenocortical disease. Design-Noncontrolled clinical trial. Animals-10 adult ferrets with clinical signs of adrenocortical disease (confirmed via serum steroid hormone concentration assessments). Procedures-Melatonin (0.5 mg) was administered orally to ferrets once daily for 1

year. At 4-month intervals, a complete physical examination; abdominal ultrasonographic examination (including adrenal gland measurement); CBC; serum biochemical analyses; and assessment of serum estradiol, androstenedione, and 17alpha-hydroxyprogesterone concentrations were performed. Serum prolactin and dehydroepiandrosterone sulfate concentrations were evaluated at the first, second, and last examinations, and serum cortisol concentration was evaluated at the first and last examinations. Results-Daily oral administration of melatonin greatly affected clinical signs of adrenocortical disease in ferrets; changes included hair regrowth, decreased pruritus, increased activity level and appetite, and decreased vulva or prostate size. Mean width of the abnormally large adrenal glands was significantly increased after the 12-month treatment period. Recurrence of clinical signs was detected in 6 ferrets at the 8-month evaluation. Compared with pretreatment values, serum 17alpha-hydroxyprogesterone and prolactin concentrations were significantly increased and decreased after 12 months, respectively. Conclusions and Clinical Relevance-Results suggest that melatonin is a useful, easily administered, palliative treatment to decrease clinical signs associated with adrenocortical disease in ferrets, and positive effects of daily treatment were evident for at least an 8-month period. Oral administration of melatonin did not decrease adrenal gland tumor growth in treated ferrets.

**Descriptors:** domestic ferrets, adrenocortical disease, melatonin, clinical signs.

Riggs, S.M., J.J. Heatley, J. Nevarez, and M.A. Mitchell (2002). **Ferret blood collection: A quick and simple technique.** *Exotic DVM* 4(6): 6-7. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferret, blood collection technique, anesthesia, blood chemistry, blood sampling.

Ritzman, T.K. and D. Knapp (2002). **Ferret orthopedics.** *Veterinary Clinics of North America. Exotic Animal Practice* 5(1): 129-155, Vii. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Orthopedic conditions requiring surgical intervention and correction frequently occur in the ferret patient. Elbow luxations and long bone fractures are among the most common syndromes affecting the ferret patient, which often presents in an emergency setting. Orthopedic conditions in the ferret, as in other mammalian species, are often the result of trauma. Surgical treatment including reduction and stabilization of the affected bony structure, combined with supervision and the recommended postoperative care, can provide a good prognosis to return to normal function for the ferret.

**Descriptors:** ferrets injuries, fracture fixation, bone fractures, forelimb injuries, bone radiography, bone therapy, hindlimb injuries.

Rosenthal, K. (2002). **The use of diagnostic imaging in ferrets.** *Veterinary Practice News* 14(1): 44. ISSN: 1528-6398.

**Descriptors:** ferrets, diagnostic imaging, diseases, computed tomography, diagnostic techniques, magnetic resonance imaging.

Rosenthal, K.L. (2002). **The basics of placing catheters, venipuncture, and what to do with the blood once you have it in ferrets and rabbits.** *Proceedings of the North American Veterinary Conference* 16: 972-974.

**NAL Call Number:** SF605.N672

**Descriptors:** ferrets, rabbits, catheters, blood sampling, venipuncture, blood.

**Notes:** In the volume: Small animal and exotics. Part of a three volume set. Meeting held January 12-16, 2002, Orlando, Florida.

Sanchez Migallon Guzman, D., J. Mayer, R. Melidone, R. McCarthy J, E. McCobb, A. Kavirayani, and J. Rush E (2006). **Pacemaker implantation in a ferret (*Mustela putorius furo*) with third-degree atrioventricular block.** *Veterinary Clinics of North America. Exotic Animal Practice* 9(3): 677-687. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** A 7.5-year-old castrated male ferret (*Mustela putorius furo*) was diagnosed with third-degree atrioventricular (AV) block. A monopolar epicardial pacemaker system was implanted, resulting in a regular, paced cardiac rhythm with third-degree AV block at 140 beats per minute. Over the next 2 months, the ferret developed anorexia, interstitial pneumonia, intermittent diarrhea, and hind-limb weakness and had a slow and progressive recovery. The ferret developed clinical signs of congestive heart failure 4 months after the surgery,

resulting in its death 3 weeks later. Necropsy results attributed the death to cardiac failure due to extensive myocardial mineralization. To the authors' knowledge this is the first published report of surgical report of surgical pacemaker implantation in a ferret.

**Descriptors:** ferret, atrioventricular block, pacemaker, implantation, congestive heart failure, myocardial mineralization.

Schoemaker, N., A. Kuijten, and H. Moorman (2006). **Alternatieven voor castratie bij fretten. [Alternatives for castration of ferrets].** *Tijdschrift Voor Diergeneeskunde* 131(2): 56. ISSN: 0040-7453.

**Descriptors:** ferrets, surgery, orchiectomy, ovariectomy, progesterone analogs, derivatives, drug implants, adverse effects, methods, progesterone therapeutic use.

**Language of Text:** Dutch.

Schoemaker, N.J. (2002). **Ferrets.** In: A. Meredith and S. Redrobe (Editors), *BSAVA Manual of Exotic Pets*, 4th edition, British Small Animal Veterinary Association: Quedgeley, UK, p. 93-101. ISBN: 0905214471.

**Descriptors:** ferrets, anesthesia, analgesics, housing, biology, diseases, diagnostic techniques, diet, drug therapy, euthanasia, handling, parasites, surgery.

Schoemaker, N.J., J.T. Lumeij, and A. Rijnberk (2005). **Current and future alternatives to surgical neutering in ferrets to prevent hyperadrenocorticism.** *Veterinary Medicine* 100(7): 484-485, 488, 490, 492, 495-496. ISSN: 8750-7943.

**NAL Call Number:** 41.8 M69

**Descriptors:** ferrets, hyperadrenocorticism, surgical neutering, alternatives, diseases.

Schoemaker, N.J., J.A. Mol, J.T. Lumeij, J.H. Thijssen, and A. Rijnberk (2003). **Effects of anaesthesia and manual restraint on the plasma concentrations of pituitary and adrenocortical hormones in ferrets.** *Veterinary Record* 152(19): 591-595. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Abstract:** Two experiments were carried out to investigate the effect of sampling techniques on the plasma concentrations of pituitary and adrenocortical hormones in ferrets (*Mustela putorius furo*). In the first experiment blood was collected on two occasions from 29 ferrets which were either manually restrained or anaesthetised with isoflurane. In the second experiment eight intact ferrets were fitted with jugular catheters and blood was collected on four occasions, just before and as soon as possible after they had been manually restrained or anaesthetised with medetomidine or isoflurane; blood was also collected 10 and 30 minutes after the induction of anaesthesia. Medetomidine anaesthesia had no effect on the plasma concentrations of pituitary and adrenocortical hormones. Isoflurane anaesthesia resulted in a significant increase in the plasma concentration of alpha-melanocyte-stimulating hormone (alpha-MSH) directly after the induction of anaesthesia. Manual restraint resulted in a significant increase in the plasma concentrations of cortisol and adrenocorticotrophic hormone (ACTH) and a decrease in the plasma concentration of alpha-MSH.

**Descriptors:** anesthesia, ferrets, restraint, specimen handling, blood chemical analysis, corticotropin, blood hydrocortisone, hyperaldosteronism, isoflurane, medetomidine, pituitary adrenal function tests.

Schoemaker, N.J., K.J. Teerds, J.A. Mol, J.T. Lumeij, J.H. Thijssen, and A. Rijnberk (2002). **The role of luteinizing hormone in the pathogenesis of hyperadrenocorticism in neutered ferrets.** *Molecular and Cellular Endocrinology* 197(1-2): 117-125. ISSN: 0303-7207.

**Abstract:** Four studies were performed to test the hypothesis that gonadotrophic hormones, and particularly luteinizing hormone (LH) play a role in the pathogenesis of ferrets: (I) adrenal glands of ferrets with hyperadrenocorticism were studied immunohistochemically to detect LH-receptors (LH-R); (II) gonadotrophin-releasing hormone (GnRH) stimulation tests were performed in 10 neutered ferrets, with measurement of androstenedione, 17alpha-hydroxyprogesterone and cortisol as endpoints; (III) GnRH stimulation tests were performed in 15 ferrets of which 8 had hyperadrenocorticism, via puncture of the vena cava under anesthesia; and (IV) urinary corticoid/creatinine (C/C) ratios were measured at 2-week intervals for 1 year in the same ferrets as used in study II. Clear cells in hyperplastic or neoplastic adrenal glands of hyperadrenocorticoid ferrets stained positive with the LH-R antibody. Plasma androstenedione and 17alpha-hydroxyprogesterone concentrations increased after stimulation with GnRH in 7 out of 8 hyperadrenocorticoid ferrets but in only 1

out of 7 healthy ferrets. Hyperadrenocorticoid ferrets had elevated urinary C/C ratios during the breeding season. The observations support the hypothesis that gonadotrophic hormones play a role in the pathogenesis of hyperadrenocorticism in ferrets. This condition may be defined as a disease resulting from the expression of LH-R on sex steroid-producing adrenocortical cells.

**Descriptors:** adrenocortical hyperfunction, ferrets, luteinizing hormone, orchiectomy, 17 alpha hydroxyprogesterone, adenoma, adrenal cortex, adrenocortical hyperfunction, androstenedione, gonadorelin, hydrocortisone, LH receptors, urine.

Schoemaker, N.J., M.H. van der Hage, G. Flik, J.T. Lumeij, and A. Rijnberk (2004). **Morphology of the pituitary gland in ferrets (*Mustela putorius furo*) with hyperadrenocorticism.** *Journal of Comparative Pathology* 130(4): 255-265. ISSN: 0021-9975.

**NAL Call Number:** 41.8 J82

**Abstract:** Pituitary tumours are the cause of hyperadrenocorticism in a variety of species, but the role of the pituitary gland in hyperadrenocorticism in ferrets is not known. In this species, the disease is mediated by the action of excess gonadotrophins on the adrenal cortex and is characterized by an excessive secretion of sex steroids. In this study, the pituitary gland of four healthy control ferrets, intact or neutered, and 10 neutered ferrets with hyperadrenocorticism was examined histologically following immunohistochemical labelling for adrenocorticotrophic hormone, alpha-melanocyte-stimulating hormone, growth hormone, thyroid-stimulating hormone, luteinizing hormone, follicle-stimulating hormone, and prolactin. Immunohistochemistry revealed that somatotrophs, thyrotrophs and lactotrophs were the most abundant cell types of the pars distalis of the pituitary gland in the healthy ferrets. The distribution of corticotrophs was similar to that in the dog and man. In ferrets, as in dogs, the melanotrophic cell was almost the only cell type of the pars intermedia. Gonadotrophs were found in the pars distalis of neutered, but not intact ferrets. All the ferrets with hyperadrenocorticism had unilateral or bilateral alterations of the adrenal gland. In addition, in the pituitary gland of two of these ferrets a tumour was detected. These tumours were not immunolabelled by antibodies against any of the pituitary hormones, and had characteristics of the clinically non-functional gonadotroph tumours seen in man. In some of the other ferrets low pituitary immunoreactivity for gonadotrophic hormones was detected, which may have been due to the feedback of autonomous steroid secretion by the neoplastic transformation of the adrenal cortex. It is concluded that initially high concentrations of gonadotrophins resulting from castration may initiate hyperactivity of the adrenal cortex. The low incidence of pituitary tumours and the low density of gonadotrophin-positive cells in non-affected pituitary tissue in this study suggest that persistent hyperadrenocorticism is not dependent on persistent gonadotrophic stimulation.

**Descriptors:** ferrets, adrenocortical hyperfunction, pituitary gland, adenoma, adrenal glands, castration, pituitary neoplasms.

Schoemaker, N.J., J. Wolfswinkel, J.A. Mol, G. Voorhout, M.J.L. Kik, J.T. Lumeij, and A. Rijnberk (2004). **Urinary glucocorticoid excretion in the diagnosis of hyperadrenocorticism in ferrets.** *Domestic Animal Endocrinology* 27(1): 13-24. ISSN: 0739-7240.

**NAL Call Number:** QL868.D6

**Abstract:** Hyperadrenocorticism in ferrets is usually associated with unaltered plasma concentrations of cortisol and adrenocorticotrophic hormone (ACTH), although the urinary corticoid/creatinine ratio (UCCR) is commonly elevated. In this study the urinary glucocorticoid excretion was investigated in healthy ferrets and in ferrets with hyperadrenocorticism under different circumstances. In healthy ferrets and in one ferret with hyperadrenocorticism, approximately 10% of plasma cortisol and its metabolites was excreted in the urine. High-performance liquid chromatography (HPLC) revealed one third of the urinary corticoids to be unconjugated cortisol; the other peaks mainly represented cortisol conjugates and metabolites. In 21 healthy sexually intact ferrets, the UCCR started to increase by the end of March and declined to initial values halfway the breeding season (June). In healthy neutered ferrets there was no significant seasonal influence on the UCCR. In two neutered ferrets with hyperadrenocorticism the UCCR was increased, primarily during the breeding season. In 27 of 31 privately owned ferrets with hyperadrenocorticism, the UCCR was higher than the upper limit of the reference range ( $2.1 \times 10^{-6}$ ). In 12 of 14 healthy neutered ferrets dexamethasone administration decreased the UCCR by more than 50%, whereas in only 1 of the 28 hyperadrenocorticoid ferrets did the UCCR decrease by more than 50%. We conclude that the UCCR in ferrets primarily reflects cortisol excretion. In healthy sexually intact ferrets and in ferrets with hyperadrenocorticism the UCCR increases during the breeding

season. The increased UCCR in hyperadrenocorticoid ferrets is resistant to suppression by dexamethasone, indicating ACTH-independent cortisol production.

**Descriptors:** ferrets, hyperadrenocorticism, disease diagnosis, urine, glucocorticoids, cortisol, excretion, metabolites, creatinine, breeding season, seasonal variation, dexamethasone, urinary corticoid-creatinine ratio (UCCR).

Schwarz, L.A., M. Solano, A. Manning, R.P. Marini, and J.G. Fox (2003). **The normal upper gastrointestinal examination in the ferret.** *Veterinary Radiology & Ultrasound* 44(2): 165-172. ISSN: 1058-8183.

**NAL Call Number:** SF757.8.A4

**Abstract:** Upper gastrointestinal examinations were performed in 11 unsedated ferrets and 4 ferrets sedated with ketamine and diazepam. Each animal received a 8-13 mL/kg body weight dosage of barium liquid (30% weight:volume). Radiographs were made immediately and at 5, 10, 20, 40, 60, 90, 120 and 150 min (mins) after the barium was administered. Gastric emptying began immediately. Mean total gastric emptying was longer in sedated ferrets (130 +/- 40 min versus 75 +/- 54 min); however, this difference was not statistically significant ( $p = 0.18$ ). Small intestinal transit time was less than 2 h in all ferrets. The barium-filled small bowel was best visualized on the 20- and 40-min radiographs and did not exceed 5-7 mm in width. Flocculation of barium in the small intestine and adherence of barium to the stomach mucosa was seen in almost all animals. The longitudinal colonic mucosal folds in the colon were well visualized in the normal upper gastrointestinal study and aided in distinguishing small intestine from large intestine. The use of ketamine and diazepam sedation did not significantly affect the parameters evaluated in the upper gastrointestinal study series.

**Descriptors:** ferrets, gastric emptying, conscious sedation, diazepam, digestive system anatomy, histology, ketamine.

Silverman, S. and L.A. Tell (2005). **Radiology of Rodents, Rabbits and Ferrets: An Atlas of Normal Anatomy and Positioning**, Elsevier Saunders: St. Louis, Missouri, USA, 299 p. ISBN: 0721697895 (hbk.).

**NAL Call Number:** SF757.8 .S56 2005

**Descriptors:** veterinary radiology, rodent anatomy, rabbit anatomy, ferret anatomy, positioning.

Taki, S., K. Suzuki, H. Suzuki, M. Sugimoto, M. Yuki, and M. Narita (2003). **Megaesophagus in ferrets: 2 case reports.** *Journal of Veterinary Medicine* 56(8): 625-629. ISSN: 0447-0192.

**Descriptors:** ferrets, megaesophagus, case reports, diseases.

**Language of Text:** Japanese.

Tunev, S.S. and M.G. Wells (2002). **Cutaneous melanoma in a ferret (*Mustela putorius furo*).** *Veterinary Pathology* 39(1): 141-143. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Abstract:** A 4-year-old spayed female ferret (*Mustela putorius furo*) was clinically evaluated for a slightly raised subcutaneous mass in the dorsal lumbar area. The mass was surgically excised and submitted for histopathologic evaluation. Histologically, the mass was composed of closely packeted large, atypical, polygonal to spindle-shaped cells arranged in sheets and short bundles. A few cells contained variable amounts of granular, brown to black intracytoplasmic pigment. Warthin-Starry and Fontana-Masson silver stains demonstrated variable numbers of fine black intracytoplasmic granules in most cells. The atypical cells stained positively for vimentin and S100 protein and negatively for cytokeratin and Melan A. Ultrastructurally, the neoplastic cells contained intracytoplasmic melanosomes in different stages of development. Compound melanosomes were not identified. To our knowledge, this report documents the first case of a spontaneous cutaneous melanoma in the ferret.

**Descriptors:** ferrets, melanoma, skin neoplasms, melanoma, ultrastructure, ovariectomy, skin pathology.

van Zeeland, Y.R., S.J. Hernandez Divers, M.W. Blasier, G. Vila Garcia, D. DeLong, and N.L. Stedman (2006). **Carpal myxosarcoma and forelimb amputation in a ferret (*Mustela putorius furo*).** *Veterinary Record* 159(23): 782-785. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Descriptors:** ferret, carpal myxosarcoma, forelimb amputation.

Vastenburg, M.H., S.A. Boroffka, and N.J. Schoemaker (2004). **Echocardiographic measurements in clinically healthy ferrets anesthetized with isoflurane.** *Veterinary Radiology & Ultrasound* 45(3): 228-232. ISSN: 1058-8183.

**NAL Call Number:** SF757.8.A4

**Abstract:** Two-dimensional, M4-mode, and color flow Doppler echocardiography was performed in 29 (18 females, 11 males) clinically healthy ferrets anesthetized with isoflurane. M-mode measurements of the left ventricle, left atrial appendage diameter (LAAD), and aorta (Ao) were obtained. The fractional shortening and LAAD/Ao ratio were calculated. The values of the M-mode measurements were compared between the male and female ferrets using a Student's t-test. No significant differences were found. The difference in body weight between the male and female ferrets was highly significant ( $P < 0.001$ ), but no significant correlation was found between body weight and M-mode measurements. Color flow Doppler examinations of the mitral, tricuspid, aortic, and pulmonary valves were recorded and there was minor valvular regurgitation in five ferrets, which was considered nonsignificant.

**Descriptors:** anesthesia, anesthetics, inhalation pharmacology, ferrets, heart ventricles, isoflurane, ultrasonography, reference values, doppler ultrasonography, echocardiography.

Vos, A., T. Muller, J. Cox, L. Neubert, and A.R. Fooks (2004). **Susceptibility of ferrets (*Mustela putorius furo*) to experimentally induced rabies with European Bat Lyssaviruses (EBLV).** *Journal of Veterinary Medicine. B, Infectious Diseases and Veterinary Public Health* 51(2): 55-60. ISSN: 0931-1793.

**Abstract:** Twenty ferrets (*Mustela putorius furo*) were inoculated by intramuscular (i.m.) injection with European Bat Lyssaviruses (EBLV) type-1 and 2 using 10(4.0) foci-forming units (FFU) EBLV-2 (n = 6), 10(4.0) FFU EBLV-1 (n = 7) and 10(6.0) FFU EBLV-1 (n = 7). Furthermore, 15 mice received 10(2.5) FFU EBLV-2 (n = 5), 10(2.5) FFU EBLV-1 (n = 5) and 10(4.5) FFU EBLV-1 (n = 5) by i.m. inoculation. All ferrets and mice receiving the higher dose of EBLV-1 succumbed to infection. In contrast, only three of seven ferrets and two of five mice inoculated experimentally with the lower EBLV-1 dose died. By comparison, all of the EBLV-2 infected ferrets and four of five mice survived infection. All 20 infected ferrets seroconverted. Using sensitive molecular tools, the virus was detected in different tissues, but it could not be found in any saliva samples taken during the 84-day observation period.

**Descriptors:** ferrets, lyssavirus, rhabdoviridae infections, DNA, viral analysis, disease susceptibility.

Wagner, R.A., C.A. Piche, W. Jochle, and J.W. Oliver (2005). **Clinical and endocrine responses to treatment with deslorelin acetate implants in ferrets with adrenocortical disease.** *American Journal of Veterinary Research* 66(5): 910-914. ISSN: 0002-9645.

**NAL Call Number:** 41.8 Am3A

**Abstract:** **OBJECTIVE:** To evaluate the clinical and endocrine responses of ferrets with adrenocortical disease (ACD) to treatment with a slow-release implant of deslorelin acetate. **ANIMALS:** 15 ferrets with ACD. **PROCEDURE:** Ferrets were treated SC with a single slow-release, 3-mg implant of deslorelin acetate. Plasma estradiol, androstenedione, and 17-hydroxyprogesterone concentrations were measured before and after treatment and at relapse of clinical signs; at that time, the adrenal glands were grossly or ultrasonographically measured and affected glands that were surgically removed were examined histologically. **RESULTS:** Compared with findings before deslorelin treatment, vulvar swelling, pruritus, sexual behaviors, and aggression were significantly decreased or eliminated within 14 days of implantation; hair regrowth was evident 4 to 6 weeks after treatment. Within 1 month of treatment, plasma hormone concentrations significantly decreased and remained decreased until clinical relapse. Mean time to recurrence of clinical signs was 13.7 +/- 3.5 months (range, 8.5 to 20.5 months). In 5 ferrets, large palpable tumors developed within 2 months of clinical relapse; 3 of these ferrets were euthanatized because of adrenal gland tumor metastasis to the liver or tumor necrosis. **CONCLUSIONS AND CLINICAL RELEVANCE:** In ferrets with ACD, a slow-release deslorelin implant appears promising as a treatment to temporarily eliminate clinical signs and decrease plasma steroid hormone concentrations. Deslorelin may not decrease adrenal tumor growth in some treated ferrets. Deslorelin implants may be useful in the long-term management of hormone-induced sequelae in ferrets with ACD and in treatment of animals that are considered at surgical or anesthetic risk.

**Descriptors:** ferrets, adrenal cortex diseases, triptorelin administration, aging, drug implants, gonadal steroid hormones.

Wenker, C. and C. Christen (2002). **Frettchen in der Tierarztpraxis. [Ferrets in veterinary practice]**. *Schweizer Archiv Fur Tierheilkunde* 144(11): 575-584. ISSN: 0036-7281.

**Abstract:** Ferrets (*Mustela putorius furo*) show up with increasing frequency in veterinary practice. Originally domesticated for hunting of rodents and rabbits, they became very popular pets which require legal permission though and the further fulfillment of various husbandry needs. Ferrets have to be maintained on a high protein diet which in practice is often done with commercial feline products. Physical examination is similar to dogs and cats whereas the frequent occurrence of non-specific symptoms require further diagnostic investigation including blood sampling, radiology, ultrasound or exploratory laparotomy. The preferred anaesthetic method is the direct face mask induction and maintenance using isoflurane without pramedication. Special attention of veterinarians has to be paid to canine distemper vaccination, the specialized reproduction physiology of the females (jills) which can develop, if unmated, a persistent oestrus with fatal consequences of hyperestrogenism, as well as the frequent occurrence of further endocrine disorders, congestive cardiomyopathy and gastrointestinal diseases.

**Descriptors:** ferrets, disease prevention and control, animal husbandry methods, anesthesia, feed, nutrition, distemper virus, handling, physical examination, rabies virus, reproduction, vaccination, viral vaccines.

**Language of Text:** German.

White, S.D. (2006). **Rabbit, rodent and ferret dermatology**. In: *Ahead of the curve: OVMA Conference Proceedings*, January 26, 2006-January 28, 2006, Ontario Veterinary Medical Association: Milton, Canada, p. 102-115.

**Online:** <http://www.ovma.org>

**Descriptors:** ferrets, rabbits, rodents, dermatology, etiology, alopecia, clinical aspects, diagnosis, drug therapy, ectoparasites, pruritus, skin diseases.

Willard, T.R. (2002). **Ferrets**. *Exotic DVM* 4(4): 36-37. ISSN: 1521-1363.

**NAL Call Number:** SF981 .E96

**Descriptors:** ferrets, anatomy, physiology, diets, feed formulation, nutrient requirements.

Wilson, G.H., C.E. Greene, and C.B. Greenacre (2003). **Suspected pseudohypoparathyroidism in a domestic ferret**. *Journal of the American Veterinary Medical Association* 222(8): 1093-1096, 1077. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** A 1.5-year-old ferret examined because of seizures was found to have low serum calcium, high serum phosphorus, and extremely high serum parathyroid hormone concentrations. Common causes of these abnormalities, including nutritional secondary hyperparathyroidism, chronic renal secondary hyperparathyroidism, tumor lysis syndrome, and hypomagnesemia, were ruled out, and a tentative diagnosis of pseudohypoparathyroidism was made. Pseudohypoparathyroidism is a hereditary condition in people that, to our knowledge, has not been identified in ferrets previously and is caused by a lack of response to high serum parathyroid hormone concentrations, rather than a deficiency of this hormone. The ferret improved after treatment with dihydrotachysterol (a vitamin D analog) and calcium carbonate. It was still doing well after 3.5 years of continued treatment.

**Descriptors:** ferrets, parathyroid hormone, pseudohypoparathyroidism, blood calcium, calcium carbonate, dihydrotachysterol, blood phosphorus, seizures, thyroid gland.

Wise, A.G., M. Kiupel, C. Isenhour, and R. Maes (2003). **Development and evaluation of molecular techniques for the diagnosis of Epizootic Catarrhal Enteritis infection of ferrets**. In: *Erkrankungen der Zootiere: Verhandlungsbericht des 41 Internationalen Symposiums uber die Erkrankungen der Zoo und Wildtiere. [Proceedings of the Institute for Zoo and Wildlife Research, Berlin, No.5], May 28, 2003-June 1, 2003, Rome, Italy*, 427-431 p.

**Descriptors:** ferrets, epizootic catarrhal enteritis, coronavirus, etiology, diagnosis, diagnostic techniques, development, feces, RNA, saliva, viral diseases.

Wise, A.G., M. Kiupel, and R.K. Maes (2006). **Molecular characterization of a novel coronavirus associated with epizootic catarrhal enteritis (ECE) in ferrets**. *Virology* 349(1): 164-174. ISSN: 0042-6822.

**Abstract:** A novel coronavirus, designated as ferret enteric coronavirus (FECV), was identified in feces of domestic ferrets clinically diagnosed with epizootic catarrhal enteritis (ECE). Initially, partial sequences of the

polymerase, spike, membrane protein, and nucleocapsid genes were generated using coronavirus consensus PCR assays. Subsequently, the complete sequences of the nucleocapsid gene and the last two open reading frames at the 3' terminus of the FECV genome were obtained. Phylogenetic analyses based on predicted partial amino acid sequences of the polymerase, spike, and membrane proteins, and full sequence of the nucleocapsid protein showed that FECV is genetically most closely related to group 1 coronaviruses. FECV is more similar to feline coronavirus, porcine transmissible gastroenteritis virus, and canine coronavirus than to porcine epidemic diarrhea virus and human coronavirus 229E. Molecular data presented in this study provide the first genetic evidence for a new coronavirus associated with clinical cases of ECE.

**Descriptors:** ferrets, coronavirus, enteritis, amino acid sequence, infections epidemiology, canine genetics, feline genetics, epizootic catarrhal enteritis (ECE).

Wyre, N.R. and L. Hess (2005). **Clinical technique: Ferret thoracocentesis.** *Seminars in Avian and Exotic Pet Medicine* 14(1): 22-25. ISSN: 1055-937X.

**NAL Call Number:** SF994.2.A1536

**Descriptors:** ferrets, anatomy, thoracocentesis, diagnostic techniques, pneumothorax, respiratory diseases.

**Notes:** Special issue: Cardiology.

Zandvliet, M.M.a. (2005). **Electrocardiography in psittacine birds and ferrets.** *Seminars in Avian and Exotic Pet Medicine* 14(1): 34-51. ISSN: 1055-937X.

**Descriptors:** electrocardiography, ECG, psittacine, *Mustela furo*, cardiac disease, parrots, ferrets.

Zitzow, L.A., T. Rowe, T. Morken, W.J. Shieh, S. Zaki, and J.M. Katz (2002). **Pathogenesis of avian influenza A (H5N1) viruses in ferrets.** *Journal of Virology* 76(9): 4420-4429. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** Highly pathogenic avian influenza A H5N1 viruses caused outbreaks of disease in domestic poultry and humans in Hong Kong in 1997. Direct transmission of the H5N1 viruses from birds to humans resulted in 18 documented cases of respiratory illness, including six deaths. Here we evaluated two of the avian H5N1 viruses isolated from humans for their ability to replicate and cause disease in outbred ferrets. A/Hong Kong/483/97 virus was isolated from a fatal case and was highly pathogenic in the BALB/c mouse model, whereas A/Hong Kong/486/97 virus was isolated from a case with mild illness and exhibited a low-pathogenicity phenotype in mice. Ferrets infected intranasally with 10(7) 50% egg infectious doses (EID(50)) of either H5N1 virus exhibited severe lethargy, fever, weight loss, transient lymphopenia, and replication in the upper and lower respiratory tract, as well as multiple systemic organs, including the brain. Gastrointestinal symptoms were seen in some animals. In contrast, weight loss and severe lethargy were not noted in ferrets infected with 10(7) EID(50) of two recent human H3N2 viruses, although these viruses were also isolated from the brains, but not other extrapulmonary organs, of infected animals. The results demonstrate that both H5N1 viruses were highly virulent in the outbred ferret model, unlike the differential pathogenicity documented in inbred BALB/c mice. We propose the ferret as an alternative model system for the study of these highly pathogenic avian viruses.

**Descriptors:** disease models, ferrets, influenza physiopathology, influenza A virus, avian pathogenicity, adolescent, child, influenza pathology and virology, lung pathology and virology, virulence, virus replication.

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### Viruses

Czub, M., H. Weingartl, S. Czub, R. He, and J. Cao (2005). **Evaluation of modified vaccinia virus Ankara based recombinant SARS vaccine in ferrets.** *Vaccine* 23(17-18): 2273-2279. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Severe acute respiratory syndrome (SARS) caused by a newly identified coronavirus (SARS-CoV) remains a threat to cause epidemics as evidenced by recent sporadic cases in China. In this communication, we evaluated the efficacy and safety of two SARS vaccine candidates based on the recombinant modified vaccinia Ankara (MVA) expressing SARS-CoV spike or nucleocapsid proteins in ferrets. No clinical signs were observed in all the ferrets challenged with SARS-CoV. On the other hand, vaccination did not prevent SARS-CoV infection in ferrets. In contrast, immunized ferrets (particularly those immunized with rMVA-spike) exhibited significantly stronger inflammatory responses and focal necrosis in liver tissue after SARS-CoV challenge than control animals. Thus, our data suggest that enhanced hepatitis is linked to vaccination with rMVA expressing SARS-CoV antigens.

**Descriptors:** ferrets, sars virus, viral vaccines, viral antigens, hepatitis, immunology, RNA, viral analysis, severe acute respiratory syndrome.

Fan, J., X. Liang, M.S. Horton, H.C. Perry, M.P. Citron, G.J. Heidecker, T.M. Fu, J. Joyce, C.T. Przysiecki, P.M. Keller, V.M. Garsky, R. Ionescu, Y. Rippeon, L. Shi, M.A. Chastain, J.H. Condra, M.E. Davies, J. Liao, E.A. Emini, and J.W. Shiver (2004). **Preclinical study of influenza virus A M2 peptide conjugate vaccines in mice, ferrets, and rhesus monkeys.** *Vaccine* 22(23-24): 2993-3003. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** A universal influenza virus vaccine that does not require frequent updates and/or annual immunizations will offer significant advantages over current seasonal flu vaccines. The highly conserved influenza virus A M2 membrane protein has been previously suggested as a potential antigen target for such a vaccine. Here, we report systematic evaluation of M2 peptide conjugate vaccines (synthetic peptides of M2 extracellular domain conjugated to keyhole limpet hemocyanin (KLH) or *Neisseria meningitidis* outer membrane protein complex (OMPC)) in mice, ferrets, and rhesus monkeys. The conjugate vaccines were highly immunogenic in all species tested and were able to confer both protection against lethal challenge of either H1N1 or H3N1 virus in mice and reduce viral shedding in the lower respiratory tracts of mice and ferrets. The protection against lethal challenge in mice could also be achieved by passive transfer of monkey sera containing high M2 antibody titers. In addition, we showed that M2 antisera were cross reactive with M2 peptides derived from a wide range of human influenza A strains, but they failed to react with M2 peptides of the pathogenic H5N1 virus (A/Hong Kong/97). The data presented here will permit better understanding of the potential of an M2-based vaccine approach.

**Descriptors:** ferrets, mice, rhesus, influenza A virus, influenza vaccines, orthomyxoviridae infections, antibodies, lung virology, *Macaca mulatta*, inbred Balb C mice, nasal mucosa virology, *neisseria meningitidis*, conjugate vaccines, virus replication.

Govorkova, E.A., J.E. Rehg, S. Krauss, H.L. Yen, Y. Guan, M. Peiris, T.D. Nguyen, T.H. Hanh, P. Puthavathana, H.T.

Long, C. Buranathai, W. Lim, R.G. Webster, and E. Hoffman (2006). **Lethality to Ferrets of H5N1 Influenza Viruses Isolated from Humans and Poultry in 2004.** *Journal of Virology* 80(12): 6195. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Descriptors:** ferrets, influenza virus, H5N1, humans, poultry, lethality.

Govorkova, E.A., J.E. Rehg, S. Krauss, H.L. Yen, Y. Guan, M. Peiris, T.D. Nguyen, T.H. Hanh, P. Puthavathana, H.T. Long, C. Buranathai, W. Lim, R.G. Webster, and E. Hoffmann (2005). **Lethality to ferrets of H5N1 influenza viruses isolated from humans and poultry in 2004.** *Journal of Virology* 79(4): 2191-2198. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** The 2004 outbreaks of H5N1 influenza viruses in Vietnam and Thailand were highly lethal to humans and to poultry; therefore, newly emerging avian influenza A viruses pose a continued threat, not only to avian species but also to humans. We studied the pathogenicity of four human and nine avian H5N1/04 influenza viruses in ferrets (an excellent model for influenza studies). All four human isolates were fatal to intranasally inoculated ferrets. The human isolate A/Vietnam/1203/04 (H5N1) was the most pathogenic isolate; the severity of disease was associated with a broad tissue tropism and high virus titers in multiple organs, including the brain. High fever, weight loss, anorexia, extreme lethargy, and diarrhea were observed. Two avian H5N1/04 isolates were as pathogenic as the human viruses, causing lethal systemic infections in ferrets. Seven of nine H5N1/04 viruses isolated from avian species caused mild infections, with virus replication restricted to the upper respiratory tract. All chicken isolates were nonlethal to ferrets. A sequence analysis revealed polybasic amino acids in the hemagglutinin connecting peptides of all H5N1/04 viruses, indicating that multiple molecular differences in other genes are important for a high level of virulence. Interestingly, the human A/Vietnam/1203/04 isolate had a lysine substitution at position 627 of PB2 and had one to eight amino acid changes in all gene products except that of the M1 gene, unlike the A/chicken/Vietnam/C58/04 and A/quail/Vietnam/36/04 viruses. Our results indicate that viruses that are lethal to mammals are circulating among birds in Asia and suggest that pathogenicity in ferrets, and perhaps humans, reflects a complex combination of different residues rather than a single amino acid difference.

**Descriptors:** ferrets, influenza virus, genetics, mortality, avian pathogenicity, orthomyxoviridae pathogenicity, influenza pathology, influenza A virus, avian classification, poultry diseases.

Govorkova, E.A., R.J. Webby, J. Humberd, J.P. Seiler, and R.G. Webster (2006). **Immunization with reverse-genetics-produced H5N1 influenza vaccine protects ferrets against homologous and heterologous challenge.** *Journal of Infectious Diseases* 194(2): 159-167. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** BACKGROUND: Multiple cases of transmission of avian H5N1 influenza viruses to humans illustrate the urgent need for an efficacious, cross-protective vaccine. METHODS: Ferrets were immunized with inactivated whole-virus vaccine produced by reverse genetics with the hemagglutinin (HA) and neuraminidase genes of A/HK/213/03 virus. Ferrets received a single dose of vaccine (7 or 15 microg of HA) with aluminum hydroxide adjuvant or 2 doses (7 microg of HA each) without adjuvant and were challenged with 10(6) 50% egg infectious doses of A/HK/213/03, A/HK/156/97, or A/Vietnam/1203/04 virus. RESULTS: One or 2 doses of vaccine induced a protective antibody response to the vaccine strain. All immunization regimens completely protected ferrets from challenge with homologous wild-type A/HK/213/03 virus: no clinical signs of infection were observed, virus replication was significantly reduced ( $P < .05$ ) and was restricted to the upper respiratory tract, and spread of virus to the brain was prevented. Importantly, all vaccinated ferrets were protected against lethal challenge with the highly pathogenic strain A/Vietnam/1203/04. The 2-dose schedule induced higher levels of antibodies that were cross-reactive to antigenically distinct H5N1 viruses. CONCLUSIONS: H5N1 vaccines may stimulate an immune response that is more cross-protective than what might be predicted by in vitro assays and, thus, hold potential for being stockpiled as "initial" pandemic vaccines.

**Descriptors:** ferrets, immunology, virology, influenza A virus, H5N1, vaccines, orthomyxoviridae infections.

**Notes:** Comment In: *J Infect Dis.* 2006 Jul 15;194(2):143-5.

Hampson, A.W. (2006). **Ferrets and the challenges of H5N1 vaccine formulation.** *Journal of Infectious Diseases* 194(2): 143-145. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Descriptors:** ferrets, immunology, virology, influenza A virus, H5N1, influenza vaccines, biosynthesis,

vaccines, orthomyxoviridae infections.

**Notes:** Comment On: J Infect Dis. 2006 Jul 15;194(2):159-67.

Herlocher, M.L., R. Truscon, S. Elias, H.L. Yen, N.A. Roberts, S.E. Ohmit, and A.S. Monto (2004). **Influenza viruses resistant to the antiviral drug oseltamivir: Transmission studies in ferrets.** *Journal of Infectious Disease* 190(9): 1627-1630. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** Three type A influenza viruses, each of which has a distinct neuraminidase-gene mutation and is resistant to the neuraminidase inhibitor oseltamivir, have been isolated. Previously, in the ferret model, an R292K mutant of a type A (H3N2) virus was not transmitted under conditions in which the wild-type virus was transmitted. This model was used to investigate whether the E119V mutant of a type A (H3N2) virus and the H274Y mutant of a type A (H1N1) virus would be transmitted under similar circumstances. Both mutant viruses were transmitted, although the H274Y mutant required a 100-fold-higher dose for infection of donor ferrets and was transmitted more slowly than was the wild type. Both the mutant and the wild-type viruses retained their genotypic characteristics.

**Descriptors:** ferrets, acetamides, antiviral agents, viral drug resistance, influenza A virus, orthomyxoviridae infections transmission, virology, disease models.

Herlocher, M.L., R. Truscon, R. Fenton, A. Klimov, S. Elias, S.E. Ohmit, and A.S. Monto (2003). **Assessment of development of resistance to antivirals in the ferret model of influenza virus infection.** *Journal of Infectious Diseases* 188(9): 1355-1361. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** We attempted to develop in vivo resistance of influenza virus to amantadine and to zanamivir, by use of the ferret model of influenza virus infection. Resistance of influenza virus A/LosAngeles/1/87 (H3N2) to amantadine was generated within 6 days, during a single course of treatment, and mutations in the M2 gene that are characteristic of human infections were observed. In contrast, during an identical single course of treatment with zanamivir, no evidence of reduced susceptibility was demonstrated. Pooled virus shed by zanamivir-treated ferrets was used to infect another group of ferrets. Twenty virus clones grew in plaque assays containing zanamivir, indicating possible reduced susceptibility; however, none exhibited reduced susceptibility to zanamivir in neuraminidase (NA) inhibition assays. Sequencing of the NA gene of these clones revealed only a noncoding nucleotide mutation at position 685. Sequencing of the hemagglutinin gene revealed mutations at positions 53, 106, 138, 145, 166, and 186. Similar to the situation in humans, amantadine use in ferrets rapidly produces antiviral resistance, but zanamivir use does not, although nucleotide changes were observed.

**Descriptors:** ferrets, amantadine, antiviral agents, influenza A virus, orthomyxoviridae infections, sialic acids, animal disease models, drug resistance, viral genetics, guanidines, hemagglutination inhibition tests, viral chemistry, RNA, reverse transcriptase polymerase chain reaction, DNA sequence analysis.

Huber, V.C. and J.A. McCullers (2006). **Live attenuated influenza vaccine is safe and immunogenic in immunocompromised ferrets.** *Journal of Infectious Diseases* 193(5): 677-684. ISSN: 0022-1899.

**NAL Call Number:** 448.8 J821

**Abstract:** Patients undergoing chemotherapy for cancer are highly susceptible to influenza virus infection. Prevention of influenza virus infection is complicated in the immunocompromised host because of suboptimal responses to the trivalent inactivated influenza vaccine (TIV). A new, live attenuated influenza vaccine (LAIV; FluMist) may offer a more effective alternative to TIV, but the safety of this LAIV in immunocompromised patients must first be established. In the present study, FluMist was administered to ferrets immunocompromised by treatment with dexamethasone and cytarabine. Ferrets exhibited no signs or symptoms attributable to FluMist, and nasal clearance of LAIV strains from immunocompromised ferrets was similar to that from control ferrets. Serum antibody responses against the vaccinating strains were analyzed as a measure of vaccine efficacy. Antibody titers to all 3 vaccine strains in immunocompromised ferrets were similar to those seen in mock-treated control ferrets, as assessed by microneutralization assay. These findings support the potential use of this vaccine in immunocompromised humans.

**Descriptors:** ferrets, blood antibodies, immunocompromised host, influenza A virus, influenza B virus, influenza vaccines, cytarabine, dexamethasone, immunosuppressive agents.

Lambkin, R., J.S. Oxford, S. Bossuyt, A. Mann, I.C. Metcalfe, C. Herzog, J.F. Viret, and R. Gluck (2004). **Strong local and systemic protective immunity induced in the ferret model by an intranasal virosome-formulated influenza subunit vaccine.** *Vaccine* 22(31-32): 4390-4396. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** The proliferation of influenza viruses causes costly, recurrent, annual epidemics. Current vaccines, mainly administered parenterally, have been shown to be suboptimal in terms of efficacy, particularly where local IgA responses are concerned. Recent investigations of virosomes as delivery systems for viral HA and NA antigens have demonstrated an improved immune response. This paper investigates the efficacy of a novel virosome-based intranasal influenza vaccine by its ability to reduce disease symptoms and its effect on viral shedding in nasal secretions of immunised ferrets. The use of ferrets in the study of influenza vaccines is based on the good comparability between ferret and human response to the disease. Intranasal, as opposed to parenteral, administration of a trivalent virosome-based subunit vaccine adjuvanted with HLT provides an almost total prevention of virus shedding combined with a high level of immunological protection against homologous virus challenge. The ease of application of an intranasal vaccine may have positive repercussions in the adoption of influenza vaccinations, particularly in 'at-risk' groups.

**Descriptors:** ferrets, orthomyxoviridae infections, intranasal administration, influenza A virus, influenza B virus, influenza vaccines, orthomyxoviridae infections, virus shedding.

Langlois, I. (2005). **Viral diseases of ferrets.** *Veterinary Clinics of North America. Exotic Animal Practice* 8(1): 139-160. ISSN: 1094-9194.

**NAL Call Number:** SF997.5.E95 E97

**Abstract:** Distemper and rabies vaccination are highly recommended because of the almost invariable fatal outcome of these conditions. Vaccination should constitute an important part of a ferret's preventative medicine program. With the current and anticipated development and licensing of new vaccines, practitioners are invited to gain awareness of the latest vaccine information. Establishment of a practice vaccination protocol with regards to the site of administration of rabies and distemper vaccines is paramount to document any future abnormal tissue reactions. Influenza is the most common zoonotic disease that is seen in ferrets. Although it generally is benign in most ferrets, veterinarians must take this condition seriously. The characteristic continuous antigenic variation of this virus may lead to more virulent strains; the recent emergence of avian influenza virus outbreaks; and the increased susceptibility of elderly, young, and immunosuppressed individuals.

**Descriptors:** ferrets, viral diseases, distemper, rabies vaccination.

Ljungberg, K., C. Kolmskog, B. Wahren, G. van Amerongen, M. Baars, A. Osterhaus, A. Linde, and G. Rimmelzwaan (2002). **DNA vaccination of ferrets with chimeric influenza A virus hemagglutinin (H3) genes.** *Vaccine* 20(16): 2045-2052. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Recently a technology was established based on homologous recombination that allowed the rapid generation of chimeric HA genes of influenza viruses, containing the antigenic determinants obtained from various influenza virus A (H3N2) viruses. In the present report plasmids were generated using a H3 HA vector handle and the hypervariable regions of two genetically distinct influenza A H3N2 viruses, A/Stockholm/7/97 and A/Netherlands/18/94. In a ferret model it was shown that immunisation with plasmid DNA encoding chimeric HA indeed elicited antibody responses specific for the virus from which the hypervariable region with the antigenic determinants were obtained. After DNA-immunisation of the ferrets, protective immunity against infection with influenza virus A/Netherlands/18/94 was evaluated.

**Descriptors:** ferrets, hemagglutinin glycoproteins, influenza virus genetics, influenza A virus, influenza vaccines, DNA vaccines, enzyme linked immunosorbent assay, lymphocyte activation, genetic recombination, T lymphocytes.

Maher, J.A. and J. DeStefano (2004). **The ferret: An animal model to study influenza virus.** *Lab Animal* 33(9): 50-53. ISSN: 0093-7355.

**NAL Call Number:** QL55.A1L33

**Abstract:** There has been much critical influenza research conducted in a little-known laboratory animal--the ferret. The authors review some of these findings, discuss the reasons the ferret often becomes a model for

influenza infection, and compare the ferret with other animal models.

**Descriptors:** ferrets, animal models, orthomyxoviridae, influenza, literature review.

Maines, T.R., L.M. Chen, Y. Matsuoka, H. Chen, T. Rowe, J. Ortin, A. Falcon, T.H. Nguyen, I.Q. Mai, E.R. Sedyaningsih, S. Harun, T.M. Tumpey, R.O. Donis, N.J. Cox, K. Subbarao, and J.M. Katz (2006). **Lack of transmission of H5N1 avian-human reassortant influenza viruses in a ferret model.** *Proceedings of the National Academy of Sciences of the United States of America* 103(32): 12121-12126. ISSN: 0027-8424.

**Abstract:** Avian influenza A H5N1 viruses continue to spread globally among birds, resulting in occasional transmission of virus from infected poultry to humans. Probable human-to-human transmission has been documented rarely, but H5N1 viruses have not yet acquired the ability to transmit efficiently among humans, an essential property of a pandemic virus. The pandemics of 1957 and 1968 were caused by avian-human reassortant influenza viruses that had acquired human virus-like receptor binding properties. However, the relative contribution of human internal protein genes or other molecular changes to the efficient transmission of influenza viruses among humans remains poorly understood. Here, we report on a comparative ferret model that parallels the efficient transmission of H3N2 human viruses and the poor transmission of H5N1 avian viruses in humans. In this model, an H3N2 reassortant virus with avian virus internal protein genes exhibited efficient replication but inefficient transmission, whereas H5N1 reassortant viruses with four or six human virus internal protein genes exhibited reduced replication and no transmission. These findings indicate that the human virus H3N2 surface protein genes alone did not confer efficient transmissibility and that acquisition of human virus internal protein genes alone was insufficient for this 1997 H5N1 virus to develop pandemic capabilities, even after serial passages in a mammalian host. These results highlight the complexity of the genetic basis of influenza virus transmissibility and suggest that H5N1 viruses may require further adaptation to acquire this essential pandemic trait.

**Descriptors:** ferrets virology, influenza A virus, H5N1, metabolism, human transmission, human virology, reassortant viruses, metabolism, disease models, virus replication.

Mann, A., A.C. Marriott, S. Balasingam, R. Lambkin, J.S. Oxford, and N.J. Dimmock (2006). **Interfering vaccine (defective interfering influenza A virus) protects ferrets from influenza, and allows them to develop solid immunity to reinfection.** *Vaccine* 24(20): 4290-4296. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Defective interfering (DI) virus RNAs result from major deletions in full-length viral RNAs that occur spontaneously during de novo RNA synthesis. These RNAs are packaged into virions that are by definition non-infectious, and are delivered to cells normally targeted by the virion. DI RNAs can only replicate with the aid of a coinfecting infectious helper virus, but the small size of DI RNA allows more copies of it to be made than of its full-length counterpart, so the cell produces defective virions in place of infectious progeny. In line with this scenario, the expected lethal disease in an influenza A virus-mouse model is made subclinical by administration of DI virus, but animals develop solid immunity to the infecting virus. Hence DI virus has been called an 'interfering vaccine'. Because interfering vaccine acts intracellularly and at a molecular level, it should be effective against all influenza A viruses regardless of subtype. Here we have used the ferret, widely acknowledged as the best model for human influenza. We show that an interfering vaccine with defective RNAs from an H3N8 virus almost completely abolished clinical disease caused by A/Sydney/5/97 (H3N2), with abrogation of fever and significant reductions in clinical signs of illness. Animals recovered fully and were solidly immune to reinfection, in line with the view that treatment converts the otherwise virulent disease into a subclinical and immunizing infection.

**Descriptors:** influenza vaccines, administration, dosage, influenza virus A immunology, ferrets, mice, orthomyxoviridae infections, immunology.

Martina, B.E.E., B.L. Haagmans, and T. Kuiken (2003). **SARS virus infection of cats and ferrets.** *Nature* 425(6961): 915. ISSN: 0028-0836.

**Abstract:** The susceptibility of the domestic cat (*Felis domesticus*) and the ferret (*Mustela furo*) to severe acute respiratory syndrome (SARS) was investigated. Cats and ferrets inoculated with SARS coronavirus were susceptible to infection and efficiently transmitted the virus to previously uninfected animals that were housed with them. These species might, therefore, be useful as animal models to evaluate antiviral drugs or vaccine candidates against SARS. The ease with which the 2 distantly related carnivores can be infected suggests that

the reservoir for SARS may involve a range of species.

**Descriptors:** ferrets, cats, SARS, virus infection, acute respiratory syndrome, transmission, reservoir.

Martinez, J., A.J. Ramis, M. Reinacher, and D. Perpignan (2006). **Detection of feline infectious peritonitis virus-like antigen in ferrets.** *Veterinary Record* 158(15): 523. ISSN: 0042-4900.

**NAL Call Number:** 41.8 V641

**Descriptors:** ferrets, antigens, detection, coronavirus, feline infectious peritonitis diagnosis, epidemiology, virology.

Mishin, V.P., M.S. Nedyalkova, F.G. Hayden, and L.V. Gubareva (2005). **Protection afforded by intranasal immunization with the neuraminidase-lacking mutant of influenza A virus in a ferret model.** *Vaccine* 23(22): 2922-2927. ISSN: 0264-410X.

**NAL Call Number:** QR189.V32

**Abstract:** Protective efficacy of the intranasal immunization with the neuraminidase (NA)-deficient mutant of the influenza A virus was investigated in ferrets. Despite the highly attenuated replication in vivo, the mutant completely protected the animals against the wild type virus challenge. When challenge was done with antigenic drift variants, significant reductions in the viral titers, inflammatory cell counts, and protein concentrations were observed in the nasal washes of the immunized animals. The genetically engineered NA-deficient mutant also protected animals against the challenge and induced humoral immune response against the foreign protein that replaced the NA. We conclude that the NA as antigen is dispensable in the live attenuated influenza virus vaccine and that the NA-lacking mutant can be used as a virus vector.

**Descriptors:** ferrets, influenza A virus, vaccine administration, neuraminidase genetics, orthomyxoviridae infections, intranasal administration, virus enzymology, genetics, animal models.

Miwa, Y., S. Matsunaga, M. Ando, H. Nakayama, K. Uetsuka, H. Nakamura, and H. Ogawa (2005). **Spontaneous Aleutian disease in a ferret infected with the ferret-derived Aleutian-disease virus strain.** *Journal of the Japan Veterinary Medical Association* 58(7): 484-487. ISSN: 0446-6454.

**Descriptors:** ferret, Aleutian disease, spontaneous, clinical aspects.

**Language of Text:** Japanese; Summary in English.

Moore, G.E., N.W. Glickman, M.P. Ward, K.S. Engler, H.B. Lewis, and L.T. Glickman (2005). **Incidence of and risk factors for adverse events associated with distemper and rabies vaccine administration in ferrets.** *Journal of the American Veterinary Medical Association* 226(6): 909-912. ISSN: 0003-1488.

**NAL Call Number:** 41.8 Am3

**Abstract:** **OBJECTIVE:** To determine incidence of and risk factors for adverse events associated with distemper and rabies vaccine administration in ferrets. **DESIGN:** Retrospective cohort study. **ANIMALS:** 3,587 ferrets that received a rabies or distemper vaccine between January 1, 2002, and December 31, 2003. **PROCEDURES:** Electronic medical records were searched for possible vaccine-associated adverse events. Adverse events were classified by attending veterinarians as nonspecific vaccine reactions, allergic reactions, or anaphylaxis. Patient information that was collected included age, weight, sex, cumulative number of distemper and rabies vaccinations received, clinical signs, and treatment. The association between potential risk factors and occurrence of an adverse event was estimated with logistic regression. **RESULTS:** 30 adverse events were recorded. The adverse event incidence rates for administration of rabies vaccine alone, distemper vaccine alone, and rabies and distemper vaccines together were 0.51%, 1.00%, and 0.85%, respectively. These rates were not significantly different. All adverse events occurred immediately following vaccine administration and most commonly consisted of vomiting and diarrhea (52%) or vomiting alone (31%). Age, sex, and body weight were not significantly associated with occurrence of adverse events, but adverse event incidence rate increased as the cumulative number of distemper or rabies vaccinations received increased. In multivariate logistic regression analysis, only the cumulative number of distemper vaccinations received was significantly associated with the occurrence of an adverse event. **CONCLUSIONS AND CLINICAL RELEVANCE:** Results suggest that in ferrets, the risk of vaccine-associated adverse events was primarily associated with an increase in the number of distemper vaccinations.

**Descriptors:** diarrhea, ferrets, rabies vaccines, adverse effects of viral vaccines, distemper virus, canine immunology, logistic models, rabies virus, vomiting.

Peltola, V.T., K.L. Boyd, J.L. McAuley, J.E. Rehg, and J.A. McCullers (2006). **Bacterial sinusitis and otitis media following influenza virus infection in ferrets.** *Infection and Immunity* 74(5): 2562-2567. ISSN: 1098-5522.

**NAL Call Number:** QR1.I57

**Abstract:** *Streptococcus pneumoniae* is the leading cause of otitis media, sinusitis, and pneumonia. Many of these infections result from antecedent influenza virus infections. In this study we sought to determine whether the frequency and character of secondary pneumococcal infections differed depending on the strain of influenza virus that preceded bacterial challenge. In young ferrets infected with influenza virus and then challenged with pneumococcus, influenza viruses of any subtype increased bacterial colonization of the nasopharynx. Nine out of 10 ferrets infected with H3N2 subtype influenza A viruses developed either sinusitis or otitis media, while only 1 out of 11 ferrets infected with either an H1N1 influenza A virus or an influenza B virus did so. These data may partially explain why bacterial complication rates are higher during seasons when H3N2 viruses predominate. This animal model will be useful for further study of the mechanisms that underlie viral-bacterial synergism.

**Descriptors:** ferrets, bacterial infection, virus infection, sinusitis, pneumonia, viral-bacterial synergism.

Pennick, K.E., M.A. Stevenson, K.S. Latimer, B.W. Ritchie, and C.R. Gregory (2005). **Persistent viral shedding during asymptomatic Aleutian mink disease parvoviral infection in a ferret.** *Journal of Veterinary Diagnostic Investigation* 17(6): 594-597. ISSN: 1040-6387.

**NAL Call Number:** SF774.J68

**Abstract:** A 2-year-old domestic ferret that appeared clinically healthy was repeatedly seropositive for Aleutian mink disease parvovirus (ADV) over a 2-year observation period. Antibody titers, determined by counter-immunoelectrophoresis, ranged from 1024 to 4096. Viral DNA also was identified in serum, urine, feces, and blood cell fractions by polymerase chain reaction analysis. Ultimately, DNA in situ hybridization revealed ADV DNA in histologic sections of various tissues and organs. These data indicate that this asymptomatic ferret was persistently infected with ADV.

**Descriptors:** ferrets, Aleutian mink disease, virology, carrier state, virus shedding, antibodies, blood, physiopathology, DNA, physiology, kidney, liver, lung, spleen, urine.

Stanton, J., L. Givens, J. Evermann, and C. Brown (2003). **Immunohistochemical analysis of two strains of lion (*Panthera leo*)-adapted canine distemper virus in ferrets (*Mustela putorius furo*).** *Veterinary Pathology* 40(4): 464-467. ISSN: 0300-9858.

**NAL Call Number:** 41.8 P27

**Descriptors:** *Panthera leo*, canine distemper virus, cross species infection, immunohistochemical analysis, ferrets, lions.

Suguitan, A. L., J. McAuliffe, K. Mills L, H. Jin, G. Duke, B. Lu, C. Luke J, B. Murphy, D. Swayne E, G. Kemble, and K. Subbarao (2006). **Live, Attenuated Influenza A H5N1 Candidate Vaccines Provide Broad Cross-Protection in Mice and Ferrets.** *PLoS Medicine* 3(9): E360. ISSN: 1549-1676.

**Abstract:** BACKGROUND: Recent outbreaks of highly pathogenic influenza A H5N1 viruses in humans and avian species that began in Asia and have spread to other continents underscore an urgent need to develop vaccines that would protect the human population in the event of a pandemic. METHODS AND FINDINGS: Live, attenuated candidate vaccines possessing genes encoding a modified H5 hemagglutinin (HA) and a wild-type (wt) N1 neuraminidase from influenza A H5N1 viruses isolated in Hong Kong and Vietnam in 1997, 2003, and 2004, and remaining gene segments derived from the cold-adapted (ca) influenza A vaccine donor strain, influenza A/Ann Arbor/6/60 ca (H2N2), were generated by reverse genetics. The H5N1 ca vaccine viruses required trypsin for efficient growth in vitro, as predicted by the modification engineered in the gene encoding the HA, and possessed the temperature-sensitive and attenuation phenotypes specified by the internal protein genes of the ca vaccine donor strain. More importantly, the candidate vaccines were immunogenic in mice. Four weeks after receiving a single dose of 10(6) 50% tissue culture infectious doses of intranasally administered vaccines, mice were fully protected from lethality following challenge with homologous and antigenically distinct heterologous wt H5N1 viruses from different genetic sublineages (clades 1, 2, and 3) that were isolated in Asia between 1997 and 2005. Four weeks after receiving two doses of the vaccines, mice and ferrets were fully protected against pulmonary replication of homologous and heterologous wt H5N1 viruses.

CONCLUSIONS: The promising findings in these preclinical studies of safety, immunogenicity, and efficacy of

the H5N1 vaccines against antigenically diverse H5N1 vaccines provide support for their careful evaluation in Phase 1 clinical trials in humans.

**Descriptors:** ferrets, mice, live attenuated influenza virus, H5N1, vaccine, cross protection.

Sweet, C., K.J. Jakeman, K. Bush, P.C. Wagaman, L.A. McKown, A.J. Streeter, D. Desai Krieger, P. Chand, and Y.S. Babu (2002). **Oral administration of cyclopentane neuraminidase inhibitors protects ferrets against influenza virus infection.** *Antimicrobial Agents and Chemotherapy* 46(4): 996-1004. ISSN: 0066-4804.

**Abstract:** Several cyclopentane inhibitors of influenza virus neuraminidase that have inhibitory activities in tissue culture similar to those of zanamivir and oseltamivir have recently been described. These new inhibitors have been examined for efficacy against a virulent H3N2 influenza virus when administered orally to infected ferrets. Preliminary studies indicated that oral administration of BCX-1923, BCX-1827, or BCX-1812 (RWJ-270201) at a dose of 5 or 25 mg/kg of body weight was active in ferrets in reducing respiratory and constitutional signs and symptoms, but these antivirals affected virus titers in the upper and lower respiratory tracts only marginally. Of the three compounds, BCX-1812 seemed to be the most efficacious and was examined further at higher doses of 30 and 100 mg/kg. These doses significantly reduced peak virus titers in nasal washes and total virus shedding as measured by areas under the curve. Virus titers in lung homogenates were also reduced compared to those in controls, but the difference was not statistically significant. As was observed with BCX-1812 at lower doses, the nasal inflammatory cellular response, fever, and nasal signs were reduced while ferret activity was not, with activity remaining similar to uninfected animals.

**Descriptors:** ferrets, antiviral agents, cyclopentanes, enzyme inhibitors, influenza A virus, neuraminidase antagonists and inhibitors, orthomyxoviridae infections, acetamides, body temperature, cell count, cyclopentanes, hemagglutination inhibition tests, lung microbiology, nasal cavity cytology.

Ter Meulen, J., A.B.H. Bakker, E.N. Van Den Brink, G.J. Weverling, B.E.E. Martina, B.L. Haagmans, T. Kuiken, J. De Kruif, W. Preiser, W. Spaan, H.R. Gelderblom, J. Goudsmit, and A.D.M.E. Osterhaus (2004). **Human monoclonal antibody as prophylaxis for sars coronavirus infection in ferrets.** *Lancet* 363(9427): 2139-2141. ISSN: 0099-5355.

**Descriptors:** ferrets, SARS infection, coronavirus infection, human monoclonal antibody, prophylaxis, severe acute respiratory syndrome, animal model.

von Messling, V., C. Springfeld, P. Devaux, and R. Cattaneo (2003). **A ferret model of canine distemper virus virulence and immunosuppression.** *Journal of Virology* 77(23): 12579-12591. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** Canine distemper virus (CDV) infects many carnivores, including ferrets and dogs, and is the member of the Morbillivirus genus most easily amenable to experimentation in a homologous small-animal system. To gain insights into the determinants of CDV pathogenesis, we isolated a strain highly virulent for ferrets by repeated passaging in these animals. Sequence comparison of the genome of this strain with that of its highly attenuated precursor revealed 19 mutations distributed almost evenly in the six genes. We then recovered a virus from a cDNA copy of the virulent CDV strain's consensus sequence by using a modified reverse genetics system based on B cells. We infected ferrets with this virus and showed that it fully retained virulence as measured by the timing of rash appearance, disease onset, and death. Body temperature, leukocyte number, lymphocyte proliferation activity, and cell-associated viremia also had similar kinetics. We then addressed the question of the relative importance of the envelope and other viral constituents for virulence. Viruses in which the envelope genes (matrix, fusion, and hemagglutinin) of the virulent strain were combined with the other genes of the attenuated strain caused severe rash and fever even if the disease onset was delayed. Viruses in which the nucleocapsid, polymerase, and phosphoprotein genes (coding also for the V and C proteins) of the virulent strain were combined with the envelope genes of the attenuated strain caused milder signs of disease. Thus, virulence-inducing mutations have accumulated throughout the genome.

**Descriptors:** ferrets, animal disease models, distemper virus, canine pathogenicity, immunosuppression, b lymphocytes immunology, DNA, canine genetics, vero cells, virulence genetics.

von Messling, V., C. Springfeld, P. Devaux, and R. Cattaneo (2003). **A ferret model of canine distemper virus virulence and immunosuppression.** *Journal of Virology* 77(23): 12579-12591. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Descriptors:** ferret, animal model, canine distemper, virulence, immunosuppression, Morbillivirus.

Vos, A., T. Muller, J. Cox, L. Neubert, and A.R. Fooks (2004). **Susceptibility of ferrets (*Mustela putorius furo*) to experimentally induced rabies with European Bat Lyssaviruses (EBLV).** *Journal of Veterinary Medicine, B, Infectious Diseases and Veterinary Public Health* 51(2): 55-60. ISSN: 0931-1793.

**Abstract:** Twenty ferrets (*Mustela putorius furo*) were inoculated by intramuscular (i.m.) injection with European Bat Lyssaviruses (EBLV) type-1 and 2 using 10(4.0) foci-forming units (FFU) EBLV-2 (n = 6), 10(4.0) FFU EBLV-1 (n = 7) and 10(6.0) FFU EBLV-1 (n = 7). Furthermore, 15 mice received 10(2.5) FFU EBLV-2 (n = 5), 10(2.5) FFU EBLV-1 (n = 5) and 10(4.5) FFU EBLV-1 (n = 5) by i.m. inoculation. All ferrets and mice receiving the higher dose of EBLV-1 succumbed to infection. In contrast, only three of seven ferrets and two of five mice inoculated experimentally with the lower EBLV-1 dose died. By comparison, all of the EBLV-2 infected ferrets and four of five mice survived infection. All 20 infected ferrets seroconverted. Using sensitive molecular tools, the virus was detected in different tissues, but it could not be found in any saliva samples taken during the 84-day observation period.

**Descriptors:** ferrets, lyssavirus, rhabdoviridae infections, DNA, viral analysis, disease susceptibility.

Wise, A.G., M. Kiupel, and R.K. Maes (2006). **Molecular characterization of a novel coronavirus associated with epizootic catarrhal enteritis (ECE) in ferrets.** *Virology* 349(1): 164-174. ISSN: 0042-6822.

**Abstract:** A novel coronavirus, designated as ferret enteric coronavirus (FECV), was identified in feces of domestic ferrets clinically diagnosed with epizootic catarrhal enteritis (ECE). Initially, partial sequences of the polymerase, spike, membrane protein, and nucleocapsid genes were generated using coronavirus consensus PCR assays. Subsequently, the complete sequences of the nucleocapsid gene and the last two open reading frames at the 3' terminus of the FECV genome were obtained. Phylogenetic analyses based on predicted partial amino acid sequences of the polymerase, spike, and membrane proteins, and full sequence of the nucleocapsid protein showed that FECV is genetically most closely related to group 1 coronaviruses. FECV is more similar to feline coronavirus, porcine transmissible gastroenteritis virus, and canine coronavirus than to porcine epidemic diarrhea virus and human coronavirus 229E. Molecular data presented in this study provide the first genetic evidence for a new coronavirus associated with clinical cases of ECE.

**Descriptors:** ferrets, coronavirus, enteritis, amino acid sequence, infections epidemiology, canine genetics, feline genetics, epizootic catarrhal enteritis (ECE).

Zitzow, L.A., T. Rowe, T. Morken, W.J. Shieh, S. Zaki, and J.M. Katz (2002). **Pathogenesis of avian influenza A (H5N1) viruses in ferrets.** *Journal of Virology* 76(9): 4420-4429. ISSN: 0022-538X.

**NAL Call Number:** QR360.J6

**Abstract:** Highly pathogenic avian influenza A H5N1 viruses caused outbreaks of disease in domestic poultry and humans in Hong Kong in 1997. Direct transmission of the H5N1 viruses from birds to humans resulted in 18 documented cases of respiratory illness, including six deaths. Here we evaluated two of the avian H5N1 viruses isolated from humans for their ability to replicate and cause disease in outbred ferrets. A/Hong Kong/483/97 virus was isolated from a fatal case and was highly pathogenic in the BALB/c mouse model, whereas A/Hong Kong/486/97 virus was isolated from a case with mild illness and exhibited a low-pathogenicity phenotype in mice. Ferrets infected intranasally with 10(7) 50% egg infectious doses (EID(50)) of either H5N1 virus exhibited severe lethargy, fever, weight loss, transient lymphopenia, and replication in the upper and lower respiratory tract, as well as multiple systemic organs, including the brain. Gastrointestinal symptoms were seen in some animals. In contrast, weight loss and severe lethargy were not noted in ferrets infected with 10(7) EID(50) of two recent human H3N2 viruses, although these viruses were also isolated from the brains, but not other extrapulmonary organs, of infected animals. The results demonstrate that both H5N1 viruses were highly virulent in the outbred ferret model, unlike the differential pathogenicity documented in inbred BALB/c mice. We propose the ferret as an alternative model system for the study of these highly pathogenic avian viruses.

**Descriptors:** disease models, ferrets, influenza physiopathology, influenza A virus, avian pathogenicity, adolescent, child, influenza pathology and virology, lung pathology and virology, virulence, virus replication.

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[Animal Welfare Information Center](#)  
United States Department of Agriculture  
National Agricultural Library



## Information Resources on the Care and Welfare of Ferrets

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### Selected Web Sites

**Ferret FAQ.** *Anon.*

**Online:** <http://www.ferretcentral.org/faq/>

**Description:** Frequently asked questions, index, photo gallery, statistics, etc.

**Ferret Facts.** *Anon.*

**Online:** <http://www.ahc.umn.edu/rar/MNAALAS/ferret.html>

**Description:** Information on diet, behavior, housing, restraint, diseases, problems, parasitism, physiology, etc.

**Pathology of the Domestic Ferret.** *Bruce H. Williams, D.*

**Online:** <http://www.afip.org/ferrets/index.html>

**Description:** Pathology, Diseases and other veterinary documents

**Domestic Ferret Issues in California.** *California Department of Fish and Game. Habitat Conservation Planning Branch.*

**Online:** [http://www.dfg.ca.gov/hcpb/species/nuis\\_exo/ferret/ferret\\_issues\\_1.shtml](http://www.dfg.ca.gov/hcpb/species/nuis_exo/ferret/ferret_issues_1.shtml)

**Description:** Provides an overview of biology and uses of the ferret, including taxonomy, physiology, diseases, history and uses.

**The Ferret Owner's Manual.** *Dick Bossart.*

**Online:** <http://www.ferret-universe.com/care/resources/ferretmanual.pdf>

**Description:** Information on nutrition, behavior, care, vaccinations, training, health, grooming, etc.

**The Effects of Environmental Enrichment in Ferrets.** *Dorothy Einon.*

**Online:** <http://www.nal.usda.gov/awic/pubs/enrich/ferrets.htm>

**Description:** A chapter from: Smith, C.P. and V. Taylor (September 1995). *Environmental Enrichment Information Resources for Laboratory Animals: 1965 - 1995: Birds, Cats, Dogs, Farm Animals, Ferrets, Rabbits, and Rodents.*

**PetEducation.com.** *Drs. Foster & Smith.*

**Online:** <http://www.peteducation.com/index.cfm?cls=11>

**Description:** Information on diseases, parasites, behavior, basic care, nutrition, first aid and more.

**NetVet-Ferrets.** *Ken Boschert, D.*

**Online:** <http://netvet.wustl.edu/ferrets.htm>

**Description:** Many links to ferret organizations, associations, information, and other information.

**Aleutian Disease in Ferrets.** *Lianne McLeod.*

**Online:** <http://exoticpets.about.com/cs/ferrets/a/aleutiandisease.htm>

**Description:** Information on Aleutian disease, a parvovirus, in ferrets.

**Ferrets.** *National Centre for the Replacement, R.a.R.o.A.i.R.N.*

**Online:** <http://www.nc3rs.org.uk/category.asp?catID=52>

**Description:** Links to information on the housing, husbandry and care of ferrets.

Reinhardt, V. and A. Reinhardt (2006). *Database on Refinement of Housing and Handling Conditions and Environmental Enrichment for Animals Kept in Laboratories: Rodents, Rabbits, Cats, Dogs, Ferrets, Farm Animals, Horses, Birds Fishes, Amphibians and Reptiles.*, [Online Database]

**Online:** <http://labanimals.awionline.org/SearchResultsSite/refine.aspx>

**NAL Call Number:** SF406.3

**Descriptors:** laboratory animals housing databases, laboratory animals environmental enrichment databases, databases, enrichment, housing.

**Code of Practice for the Housing and Care of Animals in Designated Breeding and Supplying Establishments**

**Supplement: Ferrets and Gerbils.** *UK Home Office. Science, R.a.S.*

**Online:** [http://tna.europarchive.org/20100413151426/http://scienceandresearch.homeoffice.gov.uk/animal-research/publications-and-reference/publications/code-of-practice/code\\_of\\_practice\\_part2/ferrets2835.pdf?view=Binary\(PDF|157KB\)](http://tna.europarchive.org/20100413151426/http://scienceandresearch.homeoffice.gov.uk/animal-research/publications-and-reference/publications/code-of-practice/code_of_practice_part2/ferrets2835.pdf?view=Binary(PDF|157KB))

**Description:** Part of the Animals (Scientific Procedures) Act 1986, this supplement sets standards for the housing and care of gerbils and ferrets, including minimum cage size allowances.

**Ferret.** *Wikipedia, t.f.e.*

**Online:** <http://en.wikipedia.org/wiki/Ferret>

**Description:** Information on history, pets, biology, diseases, health concerns, regulations, etc.

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