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

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

The Epidemiology of Viral Infections in Dogs and Cats

John S. Reif, D.V.M.*

In the study of infectious disease, epidemiology plays two important roles. First, one can discuss an infection in terms of its epidemiology—the body of information related to agent characteristics, host susceptibility, transmission mechanisms, specific risk factors, reservoirs, and so forth that permits us to describe the biology of the agent-host-environment interaction. Understanding the epidemiology of an infectious disease is a prerequisite to being able to suggest the most appropriate methods for prevention and control of the disease. Second, the methods of epidemiology can be applied to infectious diseases to study their occurrence and distribution in populations and to plan intervention strategies. Epidemiology is the basis of outbreak investigation, in which the origins and generation of epidemics are studied. Having established a diagnosis and settled on a course of treatment for affected animals, the well-trained clinician turns to establishing an action plan for disease prevention. Disease surveillance provides an important element in our ability to monitor the distribution and spread of disease. Control activities are assessed epidemiologically to evaluate their effectiveness. Various strategies such as vaccination and test-and-removal programs can be studied quantitatively for efficacy and economic benefit in controlled trials. Therefore, it seems appropriate to introduce a consideration of infectious diseases of small animals by reviewing some epidemiologic concepts.

DEFINITIONS

Infectious diseases are those caused by microorganisms and their products. Many authors distinguish between those agents that are transmissible from animal to animal or animal to person (that is, *communicable*) and those that are not. Infectious agents spread by contact between hosts are termed *contagious*. Those infectious agents transmitted from animal to man under natural conditions are considered *zoonotic*.

*Professor of Epidemiology, Department of Microbiology and Environmental Health, Colorado State University College of Veterinary Medicine and Biomedical Sciences, Fort Collins, Colorado

The term *infection* refers to the entry and multiplication of the infectious agent within the tissues of the host. Infection is not synonymous with *disease*. Infections may be *inapparent*, detectable only by serologic techniques. We often think in terms of the apparent cases of disease, failing to consider subclinically infected animals capable of transmitting the agent to others. Control efforts must be directed at subclinical infections as well as at clinically apparent cases.

The frequency with which infection is manifested subclinically on the one hand and by severe illness or death on the other is known as the *gradient of infection*. The ability of an agent to produce infection, disease, and death can be quantitated. *Infectivity* is measured by the seroconversion rate in a population of susceptible, exposed individuals. *Pathogenicity* refers to the ability of an agent to produce disease and is measured by the proportion of infections that result in clinical signs. *Virulence* refers to the degree to which an agent produces severe illness or death. It is determined by calculating the *case fatality rate*—that is, the proportion of clinical cases that die. Considered in these terms, a virus such as canine parainfluenza shows high infectivity, moderate to low pathogenicity, and low virulence. At the other end of the spectrum, rabies virus has only moderate infectivity, but its pathogenicity and virulence approach 100 per cent. Infectivity and pathogenicity may be modified by the dose and route of entrance of the agent.

THE INFECTIOUS DISEASE PROCESS

The Stages of Infection

The *incubation period* is an important epidemiologic feature of an infectious disease that determines in part how the agent will be propagated through populations during an epidemic. Several factors influence the incubation period, including the rate of viral multiplication, the dose of virus received, the route of entry, and the rate and extent of the immune response. The incubation period refers to the time elapsed between exposure and the development of clinical signs.

It is important to recognize that there is a period of time preceding and following the manifestation of illness during which an animal may be capable of transmitting the infectious agent. The *period of communicability* includes transmission prior to the development of disease when the animal is subclinically infected but shedding large quantities of virus. It also includes animals that continue to shed virus after clinical signs have abated. For some diseases—infectious canine hepatitis and feline calicivirus infection, for example—this period may extend for weeks to months.

Latent infections are those in which the agent is present but not detectable by conventional laboratory techniques such as isolation from pharyngeal or rectal swabs. There may be a period of “latent” infection immediately after exposure before viral replication has occurred in sufficient quantity for isolation. The latent carriers that occur in herpesvirus infections are found after the period of initial clinical disease has subsided. In feline viral rhinotracheitis (FVR), 82 per cent of experimentally infected cats became carriers following an acute illness.⁷ Under stress (intercurrent disease,

pregnancy, lactation, change in environment, corticosteroids, for example), approximately half of the latently infected cats begin to shed virus again and may experience a recrudescence of clinical illness.⁷ The latent carrier state may persist for many months following initial infection. The primary site of viral persistence in FVR carriers is the mucosa of the nasal turbinates.⁸

Reservoirs of Infection

The *reservoir* of an infectious agent is the place in nature where it lives and multiplies. Most viral infections of dogs and cats have their reservoirs in other animals of the same species because the agents are relatively host-specific. Despite the fact that cross-species infections occur with several agents, the principal hosts of epidemiologic importance in maintaining transmission are the dog and cat. Wildlife rabies represents a notable exception.

The immediate *source* of the infection is the place from which the organism is transmitted. For example, canine parvovirus (CPV) infection may be acquired by contact with the environment, human hands, clothing, contaminated food, and inanimate objects owing to the virus' ability to persist outside the host. The reservoir for CPV, however, is the dog.

The main categories of reservoir and source for canine and feline viral diseases are acute clinical cases and carriers. In controlling infectious disease, cases present fewer problems because they can usually be recognized and segregated unless clinical signs are transient or atypical.

Carriers are those animals that harbor the infectious agent in the absence of overt signs of clinical illness. They may be classified as incubationary, subclinical, convalescent, latent, and chronic. Carriers present the major problem in disease control because they are difficult to recognize without special procedures and are permitted to move freely through susceptible populations.

Incubationary carriers are capable of transmitting the agent prior to the onset of clinical signs. This phenomenon occurs in rabies as well as many other viral diseases of the dog and cat. In canine parainfluenza, there is usually enough virus in the pharynx to allow transmission before the dog begins coughing.²³

Subclinical carriers undergo a complete cycle of viral multiplication, shedding, and development of humoral antibodies without manifesting disease. Canine and feline parvovirus infections are often subclinical, especially in older animals, but result in fecal shedding of the virus.

Convalescent carriers continue to shed virus after clinical signs have disappeared. In infectious canine hepatitis, CAV-1 is shed for 6 to 9 months in the urine of recovered animals.¹⁹ The *latent carrier* state associated with herpesvirus infections such as FVR was described previously.

Chronic carriers are persistently infected animals that are capable of transmitting infections for years, sometimes for life. The reservoir of feline leukemia virus (FeLV) is the chronically infected cat. Cats infected with FeLV that do not develop neutralizing antibody have a persistent viral infection of bone marrow cells and leukocytes but may be protected from developing lymphosarcoma and leukemia by the presence of FOCMA antibody. Viremic carriers of FeLV shed virus in their saliva in high concentrations.⁵ Viral shedding from viremic carriers is constant and may persist

for years. Control of feline leukemia and FeLV-associated disorders depends in part on identification of chronic carriers and their segregation from the healthy population.¹³ Screening tests for viral antigens (ELISA) have been developed to identify viremic cats but should be followed by a more definitive procedure to identify virus-infected cats (indirect fluorescent antibody).

Transmission

The next step in the process of infection is the escape of the organism from its reservoir through a portal of exit. The predominant routes of exit of viruses from dogs and cats are the respiratory tract, alimentary tract (fecal and oral), urinary tract, and reproductive tract. Canine distemper virus (CDV), canine parainfluenza virus (CPV), canine adenovirus-2 (CAV-2), feline rhinotracheitis virus (FVR), and feline calicivirus (FCV) are shed by aerosols and secretions from the nose and pharynx. Viruses shed in feces include CDV, infectious canine hepatitis virus (CAV-1), canine coronavirus (CCV), feline infectious peritonitis virus (FIPV), canine parvovirus (CPV), and feline parvovirus, the agent of feline panleukopenia (FPL). The canine and feline herpesviruses may be found in the female reproductive tract as well as in the pharynx and oronasal secretions. Rabies virus and FeLV are shed in saliva. CAV-1, CDV, and FPV are shed in urine as well as feces.

Viral transmission in dogs and cats is generally *horizontal*, from animal to animal by direct contact or indirect mechanisms. *Vertical transmission* refers to passage of the infective agent from parent to offspring. True vertical transmission is chromosomal, with incorporation of viral genes into the nucleic acid component of all cells of the offspring. The viral genome is then perpetuated through the germ cells. Extrachromosomal or *epigenetic* vertical transmission occurs in several diseases of the dog and cat. This category includes transplacental fetal infection from an infected mother as well as neonatal infection with milk-borne virus. Transmission occurring at birth or shortly afterward by grooming, contact with vaginal secretions, or other forms of contact should be considered horizontal.

Epigenetic transmission of FeLV from viremic queens to kittens by transplacental infection may result in abortion, fetal resorption with reproductive failure, or persistent congenital infection of kittens.¹⁵ In utero transmission of FIPV appears to occur¹⁸ and has been postulated to account for a syndrome in catteries of fetal death, fading kittens, and neonatal mortality.²⁴ In utero infection of kittens with FPV produces a spectrum of responses including fetal death, resorption and infertility, abortion, mummified fetuses, and congenital cerebellar hypoplasia.¹⁶ Some kittens are born with active infections and shed virus for up to 8 weeks but remain clinically healthy.⁴ Transplacental infection with canine herpesvirus (CHV) results in early fetal death and infertility, abortion, neonatal deaths, or the development of systemic herpesvirus infections in the first 9 days of life.¹⁴

Horizontal transmission can occur by direct or indirect routes. *Direct transmission* results from contact between one animal (the source) and another (the contact). The social behavior of dogs and cats makes direct transmission a likely event. Bite wounds (rabies), licking and grooming (FeLV), and direct contact with feces (CPV, CDV, FPL), vomitus (CAV-1, CDV), urine (CAV-1, CDV), and vaginal secretions (FVR, CHV) are common modes

of contact transmission. Sick animals with infectious secretions from oropharyngeal, nasal, conjunctival, or vaginal mucous membranes are excellent sources of viral transmission in canine distemper and infectious hepatitis.

Aerosols are another form of direct contact. Droplets projected from the pharynx and nasal cavity by sneezing, coughing, or barking contain virus and result in transmission to animals in close proximity. Canine distemper, canine parainfluenza, and canine adenovirus-2 infections are spread by aerosols. Theoretically, aerosol droplets greater than 5 microns in diameter (macrodroplets) settle out rapidly. Owing to their relatively large size, aerosols do not travel more than 1 meter. In the cat, sneezing produces large droplets that travel less than 1 meter owing to the configuration of the maxillary sinuses and turbinates.²⁵ This results in an effective sneezing distance of less than 4 feet. Susceptible cats housed with cats infected with FCV remain seronegative when kept at least 4 feet apart while fomite transmission is prevented.²⁵ Close contact is also required for infection with FVR from carrier cats to contacts housed together.⁹ Control of feline viral respiratory disease is accomplished by vaccination, quarantine, preventing direct contact between cats by housing in individual cages with solid partitions, maintaining a distance of at least 4 feet between cats that face each other, and providing adequate ventilation (12 air changes per hour) and humidity control (below 50 per cent).^{10,21} Indirect transmission by fomites is prevented by regular cleaning and disinfection.

Indirect transmission of viral agents occurs from vehicles and vectors. Food and water are potential means of common vehicle spread. Contaminated drugs, biologics, blood or blood products, and intravenous fluids are additional causes of common source epidemics. *Fomites* are inanimate objects that carry viruses on their surfaces and serve as a source of indirect transmission. In the kennel and cattery, feed and water dishes, utensils, cages, animal carriers, table tops, and litter boxes frequently serve as fomites. Human hands, clothing, and shoes are also important sources of viruses that can be transmitted indirectly. In the hospital setting, *nosocomial* infections may be transmitted from animal to animal by stethoscopes, thermometers, laryngoscopes, endoscopes, anesthetic equipment, catheters, and other medical equipment.

Viruses that are transmitted by vehicles and fomites possess the ability to survive outside the host for relatively long periods. For example, the parvoviruses that produce feline panleukopenia and canine parvoviral enteritis are stable in the environment for months. Canine adenovirus-1 is resistant to disinfection, survives a wide range of temperature and pH conditions, and will survive for several days on fomites at room temperature. Feline calicivirus remains viable in the environment for up to 1 week.²¹

Indirect transmission of viruses also occurs by the airborne route when viruses are suspended in droplet nuclei of water or adhered to the surface of dust particles. Droplet nuclei are particles less than 1 micron in diameter that result from evaporation. They travel longer distances suspended in the air and borne by wind currents or ventilation systems. The author has observed an outbreak of canine distemper in a closed colony of dogs located approximately 800 yards downwind from a facility that housed dogs obtained from a shelter with endemic infection.

Vectors are invertebrates that are responsible for transmission of agents by mechanical or biological mechanisms. *Mechanical vectors* such as flies, fleas and cockroaches carry viruses passively on their mouth parts or bodies from one host to another. CPV and FPL may be transmitted occasionally by this means. In *biological vector* transmission, the organism spends part of its life cycle in the invertebrate host. The replication of the Rocky Mountain spotted fever rickettsia in the tick vector prior to transmission to a canine or human host is a good example of this form of transmission.

MEASURING FREQUENCY OF DISEASE

The occurrence of infectious disease is described in semiquantitative and quantitative terms. Some diseases occur in *sporadic* form at irregular, infrequent intervals. Others occur more regularly but at a low level of frequency and are termed *endemic* or *enzootic*. When a sudden increase in the occurrence of a disease above its expected incidence is noted, an *epidemic* or *epizootic* is in progress.

Quantitatively, *morbidity* is measured by incidence and prevalence rates. The *incidence rate* measures the number of new cases of a disease occurring in a population at risk over a specified period of time. The *prevalence rate* measures the number of cases of a disease that exist in a population at risk at a specific point in time—for example, on January 1, 1986 (*point prevalence*). Prevalence includes newly diagnosed as well as old cases. *Period prevalence* refers to the number of existing cases per population over a period of time—for example, 1 month. Multiplication of these proportions by an appropriate constant (100, 1000, 10,000) permits expression of the rate as cases per 100, 1000, or 10,000.

The term *attack rate* is used when incidence is measured during an epidemic. The *secondary attack rate* is used to describe epidemics propagated from animal to animal. The *index case* is the first animal to come to our attention during an epidemic. Cases in the group that occur from contact with the index case are included in the secondary attack rate after excluding the index case and other coprimaries from both numerator and denominator.

In order to compare rates between populations, the *crude rates* described previously must be converted into more detailed *specific rates*. Specific rates measure incidence or prevalence in population strata described by age, sex, or breed. In developing incidence rates for canine distemper, it would be useful to calculate specific rates for dogs less than 3 months of age, 4 to 6 months, 7 to 12 months, and so on, permitting a better understanding of the dynamics of the disease with respect to age. This is done by determining the number of cases of distemper at a given age (4 to 6 months, for example) and dividing by the number of susceptible dogs 4 to 6 months present during the time period to yield a series of *age-specific rates*. When populations are compared, a summary rate called an *adjusted rate* is calculated by multiplying the specific rates by a population standard and calculating adjusted number of cases by age, sex, or breed.

Small animal populations are composed of individual animals living in

family units. Lack of a census for pets has made determination of the population at risk (denominator) difficult or impossible to ascertain. Lack of denominator data has generally obviated the possibility of calculating morbidity and mortality rates for canine and feline diseases.

Large teaching hospital populations are inappropriate denominators for calculation of morbidity rates because they may not be completely representative of the population at risk. Hospital populations are subject to selection bias in admissions patterns, especially those that accept a substantial proportion of referral cases. In hospitals, *proportional morbidity rates* (PMRs) are calculated by dividing the number of cases of a disease by all other diagnoses during a time period. It should be clear, however, that when hospital-based PMRs are compared with each other as a surrogate measure for incidence, the PMRs will be affected by differences in denominators due to selection bias, as described previously.

Morbidity and mortality rates for viral diseases in dogs and cats are best measured in captive populations where the investigator can make an accurate assessment of the denominator. Binn studied epizootics of canine viral respiratory diseases in military¹ and laboratory dogs.² The epidemiology of canine parvovirus infections was investigated in a large commercial kennel.¹⁷ Multiple cat households have been used as the population to measure incidence of feline leukemia and FeLV-associated diseases.³ Francis observed a household having 134 cats over a period of 5½ years.⁶ Potkay determined the incidence of feline infectious peritonitis in a closed breeding colony over a 4-year period.²⁰ Clinical trials of vaccines, antihelminthics, or other intervention strategies can be conducted in kennels, catteries, and colonies. Glickman conducted controlled field trials of vaccines for canine infectious tracheobronchitis¹¹ and parvovirus¹² in a closed commercial breeding kennel. Animal shelters and pet shops are also suitable populations for quantitative viral disease epidemiology. Dogs or cats that attend a large show might be considered a *cohort*. If the cohort is studied longitudinally to determine which animals develop an infectious disease after their common exposure, incidence rates can be calculated.

In working with commercial kennels, shelters, and pet shops, one should be aware of the need to account for the changes in the denominator that occur over time. Denominators are subject to the dynamic forces of births, deaths, immigration, and outmigration. The shifting denominator is best handled by determining the *animal-days at risk* and then converting the resulting number to a monthly or yearly equivalent for calculation of the appropriate rate.

Serologic surveys are conducted in canine and feline populations to ascertain the frequency of antibody against a viral agent. Studies rely on a single serum measure *seroprevalence* because it is impossible to determine when infection occurred. Studies that measure antibody levels in a cohort of animals on more than one occasion over a period of time can be used to determine seroconversion and thereby develop incidence rates for infection and disease.

EPIDEMIC THEORY AND HERD IMMUNITY

In the kennel, cattery, and community environments, there are two factors that determine whether an epidemic will occur when an infected

carrier or case is introduced into the population. The *contact rate* affects both the likelihood of an epidemic and its speed of propagation. When transmission requires direct exposure to secretions or excretions (FeLV), the contact rate will be relatively low. An infected carrier may contact two or three other animals. In contrast, in aerosolized infections such as canine distemper, the effective contact rate may be 5 or greater, depending on the housing density.

Speed of viral propagation is also affected by the *generation time*, which measures the period between successive waves of an epidemic spread from animal to animal. The generation time is usually similar to the incubation period for the disease. However, generation time measures the interval between infection and maximal communicability, as opposed to onset of clinical signs. Figure 1 illustrates a propagated epidemic with an incubation period of 4 to 6 days. In the early stages of the epizootic, one can visualize the successive waves over several incubation periods. As the epidemic progresses, an increasing number of cases are seen in each time period, reflecting the likelihood of a susceptible animal contacting a case. The higher the contact rate, the steeper the ascending slope of the curve will appear. For diseases with very short incubation periods, the epidemic is compressed in time, adding to the slope of the curve. At the height of the epidemic, new contacts are likely to be with recovered or immune individuals, and the curve tails off as the susceptible population diminishes. Thus, a decrease in the effective contact rate decreases the extent and rapidity of the epidemic's propagation. An effective system of isolation can limit the spread of the epidemic while affording time to raise the level of immunity in the unexposed portion of the population. In most facilities, effective isolation of exposed individuals and segregation of affected ones are difficult to achieve in airborne infections, making them difficult to control.

The second major consideration in epidemic propagation is the *proportion of susceptibles* in the population. In an immune individual, exposure occurs but virus does not multiply effectively in the host, thus "blocking" transmission. The higher the proportion of immune individuals, the less likely transmission is to occur and the slower the epidemic's propagation. If 50 per cent of the individuals in a population are immune, the contact rate of 1 to 5 becomes, in effect, 1 to 2.5. When this proportion is raised further, transmission stops. During an epidemic, the proportion of immune individuals increases by subclinical infections and the development of cases. The epidemic stops when effective transmission no longer occurs because most of the contacts are with immunes. The transmission pattern becomes less than one to one. The rationale for vaccinating in the face of an outbreak lies in this fact and is often a critical element in stopping epidemic morbidity.

In the United States, canine rabies is no longer endemic. Sporadic cases of canine rabies occur as the result of wildlife exposures, but dog-to-dog transmission is rare. This pattern is not due to immunization of the entire canine population but to decreasing the proportion susceptible to the critical level below which dog-to-dog transmission does not occur. For canine rabies, the proportion of immunity required to prevent endemic transmission has been estimated at 70 per cent. The 30 per cent susceptible to the disease

Figure 1. Graphic representation of an epidemic of a disease (canine distemper) with an incubation period of 466 days.

Figure 2. Seasonal distribution of feline panleukopenia at the Veterinary Hospital of the University of Pennsylvania, 1964–1971. (Reprinted with permission.)

remain rabies-free because they are unlikely to experience an effective contact.

The term *herd immunity* is used to describe the phenomena that protect susceptible animals from infection when the proportion immune is high and contact rates are low. Herd immunity is achieved by interruption of transmission cycles due to the presence of immune animals blocks. Susceptible animals are protected by the barrier of immune animals around them. The susceptible can be infected when it contacts a virus shedder. This probability decreases as the proportion of immune animals increases and the contact rate decreases.

Herd immunity is an important factor underlying the periodicity of some viral diseases. Feline panleukopenia (FPL) presents an excellent example of the effects of herd immunity on seasonal cyclicity.²² In the northeastern United States, epidemics of FPL occurred perennially during the late summer and early fall (Fig. 2). During these seasonal epidemics, attack rates were highest in kittens but increased in older cats as well, illustrating involvement of all segments of the feline population. In northeastern United States, kittens are born during April and May. Maternal antibody is present in a high proportion but declines in 8 to 13 weeks, producing a large population of susceptible kittens in June and July. Figure 3 illustrates the cumulative incidence for the years 1964 to 1971 at the University of Pennsylvania. As kittens aged, increasing outdoor activity led to higher contact rates. By July, a highly susceptible population with high contact rates made epidemic transmission likely. Viral persistence in the environment added to the probability of transmission. With a build-up of immunes from natural infection and immunization, colder weather, and declining activity and contact rates, the epidemics waned in late fall.

Figure 3. Monthly incidence of feline panleukopenia at the Veterinary Hospital of the University of Pennsylvania, 1964–1971. (Reprinted with permission.)

REFERENCES

1. Binn, L. N., Lazar, E. C., Rogul, M., et al.: Upper respiratory disease in military dogs: Bacterial mycoplasmas and viral studies. *Am. J. Vet. Res.*, 29:1809–1813, 1968.
2. Binn, L. N., Lazar, E. C., Helms, A. J., et al.: Viral antibody patterns in laboratory dogs with respiratory disease. *Am. J. Vet. Res.*, 31:697–702, 1970.
3. Cotter, S. M., Essex, M., and Hardy, W. D.: Multiple cases of feline leukemia and feline infectious peritonitis in a household. *J. Am. Vet. Med. Assoc.*, 162:1053–1058, 1973.
4. Csiza, C. K., Scott, F. W., DeLahunta, A., et al.: Transplacental infections in spontaneous panleukopenia of cats. *Cornell Vet.*, 51:429–439, 1971.
5. Francis, D. P., Essex, M., and Hardy, W. D.: Excretion of FeLV by naturally infected pet cats. *Nature*, 269:252–254, 1977.
6. Francis, D. P., Essex, M., Jakowski, R. M., et al.: Increased risk for lymphoma and glomerulonephritis in a closed population of cats exposed to feline leukemia virus. *Am. J. Epidemiol.*, 111:337–346, 1980.
7. Gaskell, R. M., and Povey, R. C.: Experimental induction of feline viral rhinotracheitis: Re-excretion in FVR recovered cats. *Vet. Rec.*, 100:129–133, 1977.
8. Gaskell, R. M., and Povey, R. C.: Feline viral rhinotracheitis: Sites of virus replication and persistence in acutely and persistently infected cats. *Res. Vet. Sci.*, 27:167–174, 1979.
9. Gaskell, R. M., and Povey, R. C.: Transmission of feline viral rhinotracheitis. *Vet. Rec.*, 111:359–362, 1982.
10. Gaskell, R. M., and Wordley, R. C.: Feline viral respiratory disease. A review with particular reference to its epizootiology and control. *J. Small Anim. Pract.*, 19:1–16, 1977.
11. Glickman, L. T., and Appel, M. J.: Intranasal vaccine trial for canine infectious tracheo-bronchitis (kennel cough). *Lab. Anim. Sci.*, 31:397–399, 1981.
12. Glickman, L. T., and Appel, M. J.: A controlled field trial of an attenuated canine origin parvovirus vaccine. *Compend. Contin. Ed. Pract. Vet.*, 4:888–892, 1982.
13. Hardy, W. D., McClelland, A., Zuckerman, E. E., et al.: Prevention of contagious spread of feline leukemia virus and development of leukemia in pet cats. *Nature*, 263:326–328, 1976.
14. Hashimoto, A., Hirai, K., Yamaguchi, T., et al.: Experimental transplacental infection of pregnant dogs with canine herpesvirus. *Am. J. Vet. Res.*, 43:844–850, 1982.
15. Hoover, E. A., Rojko, J. L., and Quackerbush, S. L.: Congenital feline leukemia virus infection. *Leukemia Rev. Intl.*, 1:7–9, 1984. In Rich, M. A. (ed.): *Proceedings of the 11th International Association for Comparative Research on Leukemia and Related Diseases*. New York, Marcel Dekker, 1984.
16. Kilham, L., Margolis, G., and Colby, E. D.: Congenital infections of cats and ferrets by

- feline panleukopenia virus manifested by cerebellar hypoplasia. *Lab. Invest.*, 17:465-480, 1967.
17. Meunier, P. C., Glickman, L. T., Appel, M. J., et al.: Canine parvovirus in a commercial kennel: Epidemiologic and pathologic findings. *Cornell Vet.*, 71:96-109, 1981.
 18. Pedersen, N. C.: Feline coronavirus infections. *In* Greene, C. E. (ed.): *Clinical Microbiology and Infectious Diseases of the Dog and Cat*. Philadelphia, W. B. Saunders, 1984, pp. 514-526.
 19. Poppensiek, G. A., and Baker, J. A.: Persistence of virus in urine as a factor in spread of infectious hepatitis in dogs. *Proc. Soc. Exp. Biol. Med.*, 77:279-281, 1951.
 20. Potkay, S., Bachter, J. D., and Pitts, T. W.: Feline infectious peritonitis in a closed breeding colony. *Lab. Anim. Sci.*, 24:279-289, 1974.
 21. Povey, R. C., and Johnson, R. H.: Observations on the epidemiology and control of viral respiratory diseases in cats. *J. Small Anim. Pract.*, 11:485-494, 1970.
 22. Reif, J. S.: Seasonality, natality and herd immunity in feline panleukopenia. *Am. J. Epidemiol.*, 103:81-87, 1976.
 23. Rosenberg, F. J., Lief, F. S., Todd, J. D., et al.: Studies of canine respiratory viruses. I. Experimental infection of dogs with an SV5-like canine parainfluenza agent. *Am. J. Epidemiol.*, 94:147-165, 1971.
 24. Scott, F. W., Wells, R. C., Post, J. E., et al.: Kitten mortality complex (neonatal FIP?). *Feline Pract.*, 9:44-58, 1979.
 25. Wardley, R. C., and Povey, R. C.: Aerosol transmission of feline calicivirus. An assessment of its epidemiological importance. *Br. Vet. J.*, 133:504-508, 1977.

Department of Microbiology and Environmental Health
College of Veterinary Medicine and Biomedical Sciences
Colorado State University
Fort Collins, Colorado 80523