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CHAPTER 46

Camelids Are Not Ruminants

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WHY BE CONCERNED?

The risk of emerging, reemerging, foreign, and intentionally introduced animal disease is real, and many perceive this as a growing problem. The understanding of animal-human pathogen relationships relies on scientific information about various species and populations of animals. National regulatory statutes that provide disease protection between animals and humans must be current and must utilize up-to-date scientific data to protect human health and our food supply while not jeopardizing or overregulating any one animal.

In the United States, the U.S. Department of Agriculture (USDA), the Department of the Interior (DOI), and the Department of Homeland Security (DHS) are the federal agencies tasked with protecting the nation's wildlife, livestock industries, companion animals, human population, and the food supply from disease. The need for regulations has become more acute with the advent of modern transportation systems that allow movement of animals from any part of the world in a matter of hours. Also, our animal and human populations, along with the U.S. food supply, will now and always need to be protected against the threat of intentionally introduced animal and human disease because bioterrorism will remain a threat.

In a late December 2003 news conference, then–Secretary of Agriculture Ann Veneman made the following statement while talking about a case of bovine spongiform encephalopathy that had been diagnosed Dec. 23, 2003, in a cow in the state of Washington: "The USDA has a primary goal of using science as the basis for decisions involving livestock health matters."

It is not clear that all federal regulatory officials always use known *science* to draft regulations and apply them to risk situations. Zoo veterinarians ask only that camelids, which are classified as domestic animals, and other species of captive and free-ranging wild animals be treated fairly, using science-based consensus of understanding that may be incorporated into laws, regulations, policies, and programs. Current scientific information is the least that these populations of unique animals deserve.

CLASSIFICATION AND EVOLUTION

Camelids are not ruminants taxonomically, physiologically, or behaviorally.[7,8] Most importantly, from a veterinary standpoint, camelids and ruminants differ in susceptibility to infectious and parasitic diseases. The differences between camelids and ruminants should exclude camelids from being classified as ruminants. Nonetheless, camelids have been placed in various categories, such as "exotic animals," "wild animals," "other livestock species," and "ruminants," by state and federal regulators. Camelids have consistently been subjected to sudden, adverse regulations (some inappropriate) when an emerging disease of livestock appears on the scene.

The closing of the Canadian border to camelids when bovine spongiform encephalitis was diagnosed in a cow in Alberta, Canada, is a case in point. Camelids were classified as ruminants and subjected to all restrictions placed on ruminants. The fact that camelids have never been diagnosed with any of the transmissible spongiform encephalopathies anywhere in the world (and are not ruminants) was not given proper consideration.

When questioned about that action, the response was that ruminants are defined by an "encyclopedia" as animals that chew a cud, are cloven hoofed, and have three- or four-chambered stomachs. Regulators completely disregarded the scientific literature that clearly shows that foregut fermentation, complex multicompartmentalized stomachs, food regurgitation, and rechewing are not limited to "ruminants" but are found in species as diverse as kangaroos and nonhuman primates.[13] In kangaroos, regurgitation and rechewing is referred to as *merycism* (Greek, "chewing the cud"). Foregut fermentation and multicompartmented stomachs are also seen in many species,

Box 46-1

Classification of the Artiodactyla

Class—Mammalia
Order—Artiodactyla
- Suborder—Suiformes
  - Family—Hippopotamidae—Hippopotamuses
  - Family—Suidae—Pigs
  - Family—Tayassuidae—Peccaries
- Suborder—Tylopoda (L., "padded foot")
  - Family—Camelidae
    - *Camelus bactrianus ferus*—Wild Bactrian camel
    - *C. bactrianus*—Bactrian camel (two humps)
    - C. *dromedarius*—Dromedary camel (one hump)
    - *Lama guanacoe*—Guanaco
    - *L. glama*—Llama
    - *L. (Vicugna) pacos*—Alpaca
    - *Vicugna vicugna*—Vicuña
- Suborder—Ruminantia—Ruminants
  - Family—Tragulidae—Chevrotain, mouse deer
  - Family—Moschinae—Musk deer
  - Family—Giraffidae—Giraffe
  - Family—Cervidae—Deer, elk, caribou
  - Family—Antilocapridae—Pronghorn
  - Family—Bovidae—Cattle, bison, antelope, sheep, goats

including the hippopotamus, kangaroo, colobus monkey, and peccary.[4]

Modern paleontologic and taxonomic scientists clearly state that camelids belong in a separate suborder Tylopoda (Latin, "padded foot") in the order Artiodactyla, which is distinct from the suborder Ruminantia* (Box 46-1).

Camelid evolution began in North America 40 to 50 million years ago in the early Eocene epoch.[6,7] Separation of the Tylopoda and Ruminantia occurred early in the evolutionary process, when the progenitors of both groups were small goat-sized animals with simple stomachs.[33]

Tylopods and ruminants continued to evolve by what is known as *parallel evolution,* which is the development of similarities in separate but related evolutionary lineages through the operation of similar selective factors acting on both lines[6,7,33] (Figure 46-1).

The Pleistocene epoch was characterized by a series of periods of extreme cold and glaciations in northern North America and Europe. The last glacial retreat occurred about 10,000 years ago, marking the beginning of the Recent epoch.

Asia and Alaska are now separated by the 90-km (56-mile)–wide Bering Strait. However, during the height

*References 1, 3, 4, 7-10, 15-17, 20-24, 26-29, 32, 35, 36.

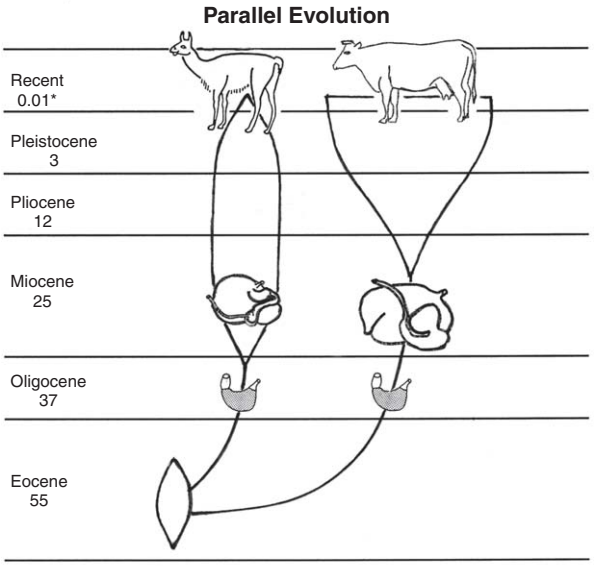

Fig 46-1 Diagram of parallel evolution of Camelidae and Ruminantia.

of one of the early Pleistocene glacial periods, the sea level was lowered sufficiently to expose a wide land bridge. Plant and animal species moved back and forth across this bridge; the camel line of Camelidae migrated from North America into Asia, where the evolutionary process continued and domestication took place.

Progenitors of the South American camelids (SACs) (guanaco, vicuña, llama, and alpaca) migrated to South America at the beginning of the Pleistocene epoch (~3 million years ago), when an open land connection between North and South America developed.[6] Evolution continued in South America, where llama and alpaca were domesticated.[9,10,35]

DIFFERENCES BETWEEN CAMELIDS AND RUMINANTS

Anatomic and physiologic differences between camelids and ruminants abound (Table 46-1).

Susceptibility to infectious and parasitic agents is of greater concern. The USDA Animal and Plant Health Inspection Service (APHIS) has stated that camelids should be classified as ruminants because, "regardless of their taxonomic classification, camelids meet the definition of ruminants and are regulated as ruminants based on their susceptibility to ruminant diseases such as foot and mouth disease, tuberculosis (*Mycobacterium bovis, M. tuberculosis,* and *M. avium*), brucellosis, Johne's disease, etc."[11]

It is true that there are diseases that camelids, cattle, sheep, and goats all acquire, but a careful appraisal of Tables 46-2 through 46-9 should dispel the myth that

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Table 46-1

Differences Between Camelids and Ruminants

	South American Camelids	Ruminants
Evolutionary pathways	Diverged 40 million years ago.	Diverged 40 million years ago.
Blood		
Red blood cells	Elliptic and small (6.5 μm).	Round and large (10 μm).
Predominant white blood cell	Neutrophil.	Lymphocyte.
Leukocytes	Up to 22,000.	Up to 12,000.
Blood glucose levels	Higher than ruminants (73-121 mg/dL).	18-65 mg/dL.
Integument		
Horns or antlers	None.	Usually present in male.
Foot	Triangular-shaped toenails and fat pad covered by soft, flexible slipper.	Has hooves and sole.
Upper lip	Split and prehensile.	Not split.
Flank fold	None.	Pronounced.
Musculoskeletal system		
Stance	Modified digitigrades.	Unguligrade ending in a hoof.
Second and third phalanges	Horizontal.	Almost vertical.
Foot	Not cloven.	Cloven.
Dewclaws	None.	Many have dewclaws.
Digestive system		
	Foregut fermenter, with regurgitation, rechewing, and reswallowing.	Same (parallel evolution).
Stomach	Three compartments not homologous with rumen, reticulum, omasum, and abomasum; all compartments have glandular epithelium; stomach motility from caudad to craniad; resistant to bloat.	Four compartments; susceptible to bloat.
Dental formula*	I 1/3, C 1/1, PM 1-2/1-2, M 3/3 × 2 = 28-32 Vicuña has incisors that continue to erupt.	I 0/3, C 0/1, PM 3/3, M 3/3 × 2 = 32
Reproduction		
Ovulation	Induced.	Spontaneous.
Estrous cycle	No.	Yes.
Follicular wave cycle	Yes.	No.
Copulation	In prone position.	In standing position.
Placenta	Diffuse and noninvasive.	Cotyledonary.
Epidermal membrane	Surrounding fetus.	None on fetus.
Cartilaginous projection on tip of penis	Yes.	No.
Ejaculation	Prolonged.	Short and intense.
Respiratory system		
Soft palate	Elongated; primarily a nasal breather.	Short; nasal or oral breather.

**I,* incisors; *C,* canines; *PM,* premolars; *M,* molars.

Continued

Table 46-1—cont'd

Differences Between Camelids and Ruminants

	South American Camelids	Ruminants
Urinary system		
Kidney	Smooth and elliptic.	Smooth or lobed.
Suburethral diverticulum	In female at external urethral orifice	None
Dorsal urethral recess	In male at junction of pelvic and penile urethra.	In some species.
Parasites		
Lice	Unique biting and sucking lice.	Lice species different.
Coccidia	*Eimeria* species (coccidia) are different.	Unique species of coccidia.
Gastrointestinal nematodes	Share some with cattle, sheep, and goats.	Share with camelids.
Infectious diseases		
Tuberculosis	Minimally susceptible.	Highly susceptible.
Bovine brucellosis	No known natural.	Highly susceptible.
Foot-and-mouth disease	Mild susceptibility.	Highly susceptible.
	Rare clinical disease with other bovine and ovine viral diseases.	
Behavior		
	Females do not lick their offspring	Females lick offspring.
	Females do not touch/lick aborted fetuses.	Females investigate dead fetuses.
	Females do not consume the placenta.	Females may consume the placenta.

Table 46-2

Clinical Infectious Diseases of Camelids and Ruminants

Camelids and Ruminants	Ruminants (Not Seen in Camelids)	Camelids (Not Seen in Ruminants)
Contagious ecthyma	Malignant catarrhal fever	Camelpox
Rabies (common to many mammals)	Bovine leukemia	Camel papillomatosis
Foot-and-mouth disease (FMD; occurs in many nonruminants)	Cowpox	*Mycoplasma hemolama* (Eperythrozoonosis)
Rinderpest (camels)	Pseudorabies	Lama adenoviruses, serotypes 1-6
West Nile virus (WNV) encephalopathy (seen in many mammals and birds)	Bovine papillomatosis	
Fungal diseases (ringworm) (common to many mammals)	Ovine progressive pneumonia	
Tetanus and other clostridial diseases	Sheeppox or goatpox	
Bovine tuberculosis (seen in many nonruminant species)	Balanoposthitis	
Johne's disease	Sheep or goat papillomatosis	
Necrobacillosis	Scrapie	
Streptococcosis (common to many nonruminant species)	Bovine spongiform encephalopathy (BSE)	
Staphylococcosis (common to many nonruminant species)	Chronic wasting disease (CWD) of cervids	
Caprine/ovine brucellosis	Bovine brucellosis Anaplasmosis	

Table 46-3

Infectious Disease Agents Producing Antibody Response, but Rare or No Clinical Disease in Camelids

Agent	Disease
Bovine herpesvirus type 1	Infectious bovine rhinotracheitis
Equine herpesvirus type 1	Equine rhinopneumonitis Retinal degeneration in SACs
Bluetongue/epizootic hemorrhagic disease virus	Bluetongue, epizootic hemorrhagic disease of deer
Rift Valley fever virus (camels)	Rift Valley fever
Rotavirus	Enteritis (diarrhea)
Coronavirus	Enteritis (diarrhea)
Adenovirus	Enteritis (diarrhea)
Encephalomyocarditis virus	Encephalomyocarditis (EMC)
Brucella abortus	Bovine brucellosis
Borna disease virus	Viral encephalitis
Vesicular stomatitis virus	Vesicular stomatitis

SACs, South American camelids.

Table 46-4

Programmed Diseases of Ruminants in United States Compared with Camelids and Other Species

	CLINICAL DISEASES IN CAMELIDS			
Programmed Diseases of Cattle, Sheep, and Goats	**From Natural Transmission**	**From Experimental Inoculation**	**Antibody Response in Camelids**	**Nonruminant Hosts Developing Natural Disease**
Bovine brucellosis *Brucella abortus*	None	Yes	Yes	Humans, horses (fistula of withers), carnivores, marine mammals
Bovine tuberculosis *Mycobacterium bovis*	Yes (rare)	Yes	Yes	Humans, European badger, brush-tailed possum
Chronic wasting disease (CWD) of cervids	None	None	None	None
Scrapie	None	None	Not applicable	None

Table 46-5

Comparison of Ruminant Emergency Conditions, Compared with Camelid and Other Species

	CLINICAL DISEASES IN CAMELIDS				
Emergency Conditions of Cattle, Sheep, and Goats	**From Natural Transmission**	**From Experimental Inoculation**	**Antibody Response in Camelids**	**Nonruminant Hosts Developing Natural Disease**	**Nonruminant Hosts, Experimental Disease**
Anthrax	Yes	Not reported	Not reported	Humans, numerous species of mammals	Many
Bovine spongiform encephalopathy (BSE)	No	No	Not applicable	Human, cat, cheetah, lion, tiger, puma	Brain extracts from infected cattle have produced disease in cattle, sheep, pigs, and mice.
Contagious bovine pleuropneumonia (mycoplasmosis)	No	Not reported	Not reported	None	Not reported
Foot-and-mouth disease (FMD)	Yes (rare)	Yes	Yes	Hedgehogs, pigs, peccaries, insectivores, xenarthra, rabbits, squirrel, hyrax, elephant, bears, marsupials	
Hemorrhagic septicemia *Pasteurella multocida* + other agents	None reported	Not reported	None reported	Broad range of mammals	Wide variety
Malignant catarrhal fever (African)	None reported	Not reported	One llama	Pigs (Norway)	Rabbit
Rift Valley fever	Yes, camel	Not reported	None reported	Human, dog, cat, rodents	Unknown
Rinderpest	Yes, camel	Not reported	Yes	Pig, peccary	Pig, peccary, dog, elephant, hyena, jackal, tiger, vulture, zebra
Vesicular stomatitis	Yes (rare)	Yes	Yes	Horse, pig	Unknown
Contagious agalactia (mycoplasmosis)	None reported	Not reported	Not reported	None	Unknown
Contagious caprine pleuropneumonia (mycoplasmosis)	None reported	Not reported	Not reported	None	Unknown
Heartwater *Ehrlichia* (formerly *Cowdria*) *ruminantium*	None reported	Not reported	Not reported	Numerous vertebrates may be intermediate hosts for *Ehrlichia*	Unknown
Nairobi sheep disease (tick borne, viral)	None reported	Not reported	Not reported	African field rat	Not successful at experimental transmission
Peste des petits ruminants	None reported	Not reported	Not reported	Not reported	Unknown
Pulmonary adenomatosis	None reported	Not reported	Not reported	Not reported	Unknown

Table 46-6

Comparison of Regulated Infectious and Parasitic Diseases of Ruminants Compared with Camelids and Other Species

	CLINICAL DISEASES IN CAMELIDS			
Regulated Diseases of Cattle, Sheep, and Goats	**From Natural Transmission**	**From Experimental Inoculation**	**Antibody Response in Camelids**	**Nonruminant Hosts Developing Natural Disease**
Rabies	Yes	Not reported	Yes	Most species of mammals
Bovine brucellosis *Brucella abortus*	None	Yes	Yes	Human, horse, carnivore, marine mammals
Bovine tuberculosis *Mycobacterium bovis*	Yes (rare)	Yes	Yes	Human, European badger, brush-tailed possum
Bovine scabies (mange) *Sarcoptes scabiei, Psoroptes ovis*	Yes	Not applicable	Not applicable	Many mammal species
Trichomoniasis *Tritrichomonas fetus*	None reported	Not reported	Not applicable	Unknown
Caprine/ovine brucellosis *Brucella melitensis*	Yes	Not reported	Yes, may cross react with bovine brucellosis	Human
Scrapie	None	Not reported	Not applicable	None
Sheep/goat scabies *Psoroptes ovis*	Yes	Not applicable	Not applicable	Unknowns

Table 46-7

Monitored Diseases of Ruminants in United States Compared with Camelids and Other Species

	CLINICAL DISEASES IN CAMELIDS				
Monitored Diseases of Cattle, Sheep, and Goats	**From Natural Transmission**	**From Experimental Inoculation**	**Antibody Response in Camelids**	**Nonruminant Hosts, Developing Natural Disease**	**Nonruminant Hosts, Experimental Disease**
Avian tuberculosis	Yes	None reported	Yes	Many species of birds and mammals; swine; humans	Unknown
Anaplasmosis	No	Yes	Yes	None	Unsuccessful attempts
Bluetongue	Yes, but with questions	Not reported	Yes	None	Raccoon, opossum, hares
Bovine leukosis, viral	None reported	Not reported	Not reported	None	Unknown
Johne's disease	Yes	Not reported	Yes	Rabbits, nonhuman primates	Unknown
Malignant catarrhal fever (North America)	None reported	Not reported	Not reported	None	Unknown
Bovine cysticercosis	None reported	Not reported	Not applicable	Human *Taenia saginata*	None reported
Infectious bovine rhinotracheitis	None reported	Not reported	Yes	None reported	Unknown
Bovine genital campylobacteriosis (vibriosis)	None reported	Not reported	Not reported	None reported	None reported

Continued

Table 46-7—cont'd

Monitored Diseases of Ruminants in United States Compared with Camelids and Other Species

	CLINICAL DISEASES IN CAMELIDS				
Monitored Diseases of Cattle, Sheep, and Goats	**From Natural Transmission**	**From Experimental Inoculation**	**Antibody Response in Camelids**	**Nonruminant Hosts, Developing Natural Disease**	**Nonruminant Hosts, Experimental Disease**
Echinococcosis	Yes	Not reported	Not applicable	Humans, carnivores	Unknown
Leptospirosis	Yes	Not reported	Yes	Numerous mammals	Rodents and rabbits
Ovine progressive pneumonia (Maedi-Visna)	None reported	Not reported	Not reported	None reported	None reported
Q fever	None reported	Not reported	Not reported	Humans and many other species	None reported
Caprine arthritis/ encephalitis	None reported	Not reported	Not reported	None reported	Unknown
Ovine chlamydiosis *Chlamydia psittaci*	None reported	Not reported	Not reported	Birds, humans, koala	Numerous species
Ovine epididymitis *Brucella ovis*	None reported	Not reported	Not reported	None	None

Table 46-8

Comparison of Regulated Parasitic Diseases of Cattle, Sheep, and Goats with Camelids

Regulated Parasitic Diseases of Cattle and Sheep	**Etiology**	**Status in Camelids**	**Intermediate Hosts**	**Location in Host**
Screwworm myiasis	*Cochliomyia hominivorax* or *Chrysomyia bezziana*	All animals, including camelids, may become infested with screwworms.	None	Wounds, necrotic tissue
African trypanosomiasis (surra)	*Trypanosoma evansi*	Important disease of camels; may involve other species of *Trypanosoma.* SACs also infected.	Blood-sucking flies (tabanids, *Stomoxys*), tsetse flies, and other	Blood
Bovine babesiosis (piroplasmosis)	*Babesia bovis*	No verified reports in either camels or SACs	Ticks	Blood
Theileriosis (East Coast fever, corridor disease)	*Theileria* spp.	No verified reports in either camels or SACs	Ticks	Blood
Cattle scabies (multiple types)	*Sarcoptes scabiei, Psoroptes ovis*	Both may infest camelids.	None, direct contact	Skin
Sheep scabies	*Psoroptes ovis*	Yes	None, direct contact	Skin
Echinococcosis (hydatid disease)	*Echinococcus granulosum*	Many species, including camelids	Carnivore is primary host; herbivores are intermediate host.	Variable, but liver and lungs common

SACs, South American camelids.

Table 46-9

Comparison of Selected Parasitic Diseases of Ruminants with Camelids

Parasitic Diseases of Ruminants	Etiology in Ruminants	Status in Camelids	Etiology in Camelids	Location in Host	Comments
Pediculosis (lice)	Biting lice *Damalinia bovis* (cattle) *Damalinia ovis* (sheep) Sucking lice in ruminants (*Haematopinus, Linognathus,* and *Solenopotes*)	None of the lice of ruminants infect camelids, or vice versa.	Biting louse of SACs: *Damalinia breviceps;* none in camels Sucking lice: *Microthoracis* spp. *(M. cameli, M. mazzai, M. minor, M. praelongiceps)*	Skin	Biting lice do not readily respond to ivermectin therapy.
Coccidiosis	*Eimeria bovis, E. zuernii,* and many other *Eimeria* spp.	Not a common parasite, and usually only in young animals	*Eimeria lamae, E. alpacae, E. punoensis, E. macusaniensis, E bactriani, E. cameli, E. dromedarii, E. pellerdyi*	Small intestine	It is common to find coccidia in feces, but animals should not be treated unless clinical syndrome is severe.
Trichuriasis (whipworms)	*Trichuris ovis*	Common	*Trichuris tenuis*	Large intestine	Serious parasite of camelids
Nematodiriasis	*Nematodirus* spp.	May be a significant parasitism	*Nematodirus battus, N. lamae*	Small intestine	
Spiculopteragiasis	Does not affect cattle, sheep, or goats in South America	Found only in South America Unique to SACs	*Spiculopteragia peruviana*	Small intestine	
Graphinemiasis	Does not affect cattle, sheep, or goats in South America	Found only in South America Unique to SACs	*Graphinema aucheniae*	Small intestine	
Lamanemiasis	Does not affect cattle, sheep, or goats in South America	Llama is secondary host. Primary host is a rodent (viscacha).	*Lamanema chavezii*	Small intestine	Serious parasite of young alpacas Affects the liver

Data from Fowler ME: *Medicine and surgery of South American camelids,* ed 2, Ames, 1998, Iowa State University Press; Wernery U, Kaaden OR: *Infectious diseases in camelids,* ed 2, Boston, 2002, Blackwell Science; and Bowman DD: *Georgis' parasitology for veterinarians,* ed 8, Philadelphia, 2003, Saunders
SACs, South American camelids.

"llamas and alpacas are susceptible to all cattle and sheep diseases."[34] In fact, they are quite resistant to many regulated ruminant diseases.

Foot-and-mouth disease (FMD) virus is highly contagious in cattle and sheep. When llamas and alpacas were first imported from South America to the United States for the blossoming private llama industry, government officials expressed concern that llamas and alpacas might pose a risk for the introduction of FMD to the United States. The USDA expended considerable experimental effort to determine the risk. It was concluded that llamas and alpacas could be infected by inoculation but did not acquire FMD when cohabiting with infected swine, in contrast with almost 100% of cattle that acquired the infection.[6,25,30] The virus could not be detected after 14 days postinoculation.

The same could be said for vesicular stomatitis. Only one animal has been diagnosed with the natural disease.[2] Llamas may be infected experimentally.[14]

Bovine tuberculosis (TB) caused by *Mycobacterium bovis* is another concern of government officials. Llamas and alpacas have developed the disease under natural conditions, when cohabiting with infected elk, but have shown resistance to acquiring TB, in contrast to ruminants.[31]

Llamas and alpacas have been experimentally infected with *Brucella abortus*, but the natural disease does not occur in these species.[12,13]

There are no reports of the transmission of any regulated ruminant disease from camelids to ruminants.

CONCLUSION

Camelids are not ruminants taxonomically, anatomically, physiologically, or behaviorally. Camelids also are not a threat to the livestock industry because they either have total resistance to infection or have minimal susceptibility to the infectious and parasitic diseases of ruminants.

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