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

CHAPTER

15

Biology and Diseases of Ruminants (Sheep, Goats, and Cattle)

Wendy J. Underwood, DVM, MS, DACVIM[a], *Ruth Blauwiekel, DVM, PhD, DACLAM*[b], *Margaret L. Delano, MS, DVM*[a], *Rose Gillesby, DVM*[c], *Scott A. Mischler, DVM, PhD, DACLAM*[d] *and Adam Schoell, DVM, DACLAM*[e]

[a]Eli Lilly and Company, Indianapolis, Indiana, USA [b]University of Vermont, Hills Building, Carrigan Drive, Burlington, VT, USA [c]Veterinary Services and Biocontainment Research, Animal Research Support, Zoetis, Richland, MI, USA [d]Worldwide Comparative Medicine, Pfizer Inc., Middletown Rd., Pearl River, NY, USA [e]Zoetis, Portage St, Kalamazoo, MI, USA

OUTLINE

I. INTRODUCTION

Since the first edition of this book, the use of ruminants as research subjects has changed dramatically. Formerly large animals were used primarily for agricultural research or as models of human diseases. Although ruminants have continued in their traditional agricultural research role, they are now extensively used for studies in molecular biology, genetic engineering and biotechnology for basic science, agricultural, and clinical applications. Concern and interest for the welfare for these species and improved understanding of their biology

Laboratory Animal Medicine, Third Edition
DOI: http://dx.doi.org/10.1016/B978-0-12-409527-4.00015-8

TABLE 15.1 Terminology

Species	Female	Male	Young animals	Castrated male	Parturition
Cattle	Cow	Bull	Calf (heifer calf, bull calf)	Steer	Calving
			Heifer (nulliparous female)		
Sheep	Ewe	Ram	Lamb (ewe lamb, ram lamb)	Wether	Calving
Goat	Doe or nanny	Buck or billy	Kid or goatling	Wether	Kidding

and behavior have continued and are reflected in changing husbandry and management systems. This chapter addresses basic biology, husbandry, and the more common or important diseases of the three ruminant species used most commonly in the laboratory, namely sheep, goats, and cattle. One chapter is simply not adequate, however, to address the many details and complexities of biology, management, and diseases of these species. References provided at the end of this chapter and noted in the text offer more information to the interested reader.

A. Taxonomy

Sheep, goats, and cattle are ungulates, 'hooved' animals that are members of the Order Artiodactyla (animals with cloven hooves), suborder Ruminatia (ruminants or cud-chewing animals) and Family Bovidae. Members of the Bovidae group of mammals are distinguished by characteristics such as even number of toes, a compartmentalized forestomach, and horns. These animals are herbivores, and as adults, derive all their glucose from gluconeogenesis. The subfamily Capra includes sheep and goats. The genus and subgenus *Ovis* includes domestic sheep as well as wild Asian and European sheep species. Domestic sheep are *Ovis aries*. *Capra hircus* is the domestic goat which originated from western Asian goats. The subfamily Bovinae and genus *Bos* include all domestic and wild cattle, including the yak and Banteng (Bali cattle). The subgenus *Taurus* contains all of today's domestic cattle. *Bos taurus* (domestic cattle) originate from the European continent, and have no hump over the withers. *Bos indicus*, known as Zebu cattle, have a hump over the withers and drooping ears.

There are many breeds of sheep worldwide that are distinguished as either 'meat,' 'wool,' or 'dual' purpose breeds. Some wool or hair breeds have varying coat colors. Some breeds are raised for milk (cheese) production. Common breeds raised for meat in the United States include the Dorset, Columbia, Suffolk, and Hampshire. Slightly smaller meat breeds include the Southdown and Border Cheviot. Wool breeds include the Merino, Rambouillet, Lincoln, and Romney and are subclassified according to properties of the wool.

Goat breeds are numerous and are usually classified according to use as dairy-, meat-, fiber-, or skin-type breeds. The major dairy breeds are the Alpine, Nubian, Toggenburg, La Mancha, and Saanen, all of which have origins on the European continent. The Nubian breed was developed from crossbreeding British stock with Egyptian and Indian goats. Fiber breeds include the Angora and the Cashmere. The La Mancha has rudimentary ears that are a genetically dominant distinguishing characteristic of the breed. Meat breeds include the Boer, Kiko, and Pygmy.

Most breeds of cattle are classified as 'dairy' or 'beef,' while a few breeds are considered 'dual-purpose.' Common dairy breeds in the United States include Holstein (also known as 'Holstein–Friesian'), Brown Swiss, Jersey, Ayrshire, and Guernsey. Holsteins and Brown Swiss have the largest body size, while Jerseys have the smallest. Of the many beef breeds, the more common in the United States include Angus, Hereford, and Simmental.

More detailed information regarding these and other ruminant breeds is available (Integrated Taxonomic Information System: http://www.itis.gov). Minor breeds of sheep, goats, and cattle are studied for their genetic and production characteristics. Discussions of these and efforts at conservation are described in detail elsewhere (American Livestock Breeds Conservancy, http://www.albc-usa.org; Gibbs *et al.*, 2009).

Some of the terminology used with respect to ruminants is given in Table 15.1.

B. Comments About and Examples of Use in Research

Ruminants have been used as research models since the inception of the Land Grant College System, first in production agriculture, and now also in anatomic and physiologic sciences and in biomedical research. Healthy, normal young ruminants serve as models of cardiac transplantation and as pre-clinical models for evaluation of cardiac assist or prosthetic devices such as vascular stents or cardiac valves (Salerno *et al.*, 1998). Ruminants have been useful research subjects for reproductive research such as embryo transfer, artificial insemination (AI), and control of the reproductive cycle (Wall *et al.*, 1997). Several important milestones in gene transfer, cloning, and genetic engineering techniques

have been developed or demonstrated using these species (Cibelli *et al*., 1998a, b). One of many proposed uses of genetically engineered ruminants is the production of proteins to be secreted in the milk and later isolated. Healthy sheep and goats are also often used for antibody production.

Genome mapping has developed rapidly since 1998. The *Genome Sequence of Taurine Cattle: A Window to Ruminant Biology and Evolution* is available for ruminants and other domestic species (Elsik *et al*., 2009). Other references for genome mapping exist (Broad *et al*., 1998; Womack, 1998; http://www.marc.usda.gov/genome/sheep/sheep.html; http://www.marc.usda.gov/genome/cattle/cattle.html).

Sheep provide obvious benefits over the use of cattle in research from the standpoint of size, ease of handling, and cost of maintenance. Sheep are widely used models for basic and applied fetal and reproductive research. The species is used for investigating circadian rhythms and the interaction between olfactory cues and behavior. Natural disease models include congenital hyperbilirubinemia/hepatic organic anion excretory defect (Dubin–Johnson Syndrome) in the Corriedale breed, congenital hyperbilirubinemia/hepatic organic anion uptake defect (Gilbert's syndrome) in the Southdown breed, gamma-glutamyl carboxylase deficiency in Rambouillets, lysosomal storage diseases, and pulmonary adenomatosis (Jaagsiekte) in several breeds. Induced models include arteriosclerosis, hemorrhagic shock, copper poisoning (Wilson's disease), and metabolic toxicosis. Sheep have been utilized as research models for orthopedic procedures, airway disease/asthma and in the areas of human device, drug discovery, and implantation research (Easley *et al*., 2008; Griffiths *et al*., 2010; Herfat, 2005; Scheerlinck *et al*., 2008).

Goats are used in a wide variety of disciplines such as immunology, mastitis, and nutrition and parasitology. Vascular researchers select the goat because of the large, readily accessible jugular veins. Goats with inherited caprine myotonia congenita ('fainting goats') have been used as a model for human myotonia congenita, or Thomson's disease (Kuhn, 1993). A line of inbred Nubians serve as models for beta-mannosidosis and prenatal therapeutic cell transplantation strategies (Lovell *et al*., 1997). These disorders are discussed in more detail later under genetic diseases. Goats are also used as a model for osteoporosis research (Welch *et al*., 1996).

Cattle are often used as a source of ruminal fluid for research, teaching, or treatment of other cattle, by placing a permanent fistula in the left abdominal wall to allow sampling of ruminal fluid (Dougherty, 1981). Cattle also serve as models of many infectious diseases and several inherited metabolic diseases. Bovine trichomoniasis, caused by *Tritrichomonas (Trichomonas) fetus* has been identified as a useful model for the human infection by *Trichomonas vaginalis* (Corbeil, 1995). Inherited cardiomyopathies have been found in the Holstein and other breeds (Weil *et al*., 1997). Lipofuscinosis has been identified in Ayrshires, glycogenosis in Shorthorn and Brahman cattle, and hemochromatosis in Salers. Holstein cattle serve as a model for leucocyte adhesion deficiency syndrome (AFIP, 1995) and achrondroplasia occurs in several breeds.

C. Availability and Sources

Common breeds of normal healthy ruminants are usually readily available, although seasonality may play a role as noted below. Agricultural sources may be located through agricultural schools, cooperative extension, and regional breeders' associations. Commercial sources of purpose-bred animals are found in technical publications and research animal vendor listings.

Purpose-bred research sheep and goats are available from commercial vendors and are usually maintained in registered facilities under federal standards that are also acceptable to research animal accrediting agencies. These animals are frequently described as 'specific pathogen free' (SPF) and are housed as biosecure or closed flocks. Animal health programs are in place and health reports usually are available on request. Agricultural sources of sheep or goats may be acceptable depending on specific research needs. Lambs and kids may be difficult to locate in fall and winter months because most breeds of sheep and goats are seasonal breeders.

Most cattle used as animal models in research in the United States are Holstein, because this dairy breed is now the most common. Purpose-bred, SPF research cattle are not typically available. Due to selection and the management of dairy production units, calves and young stock are available year round. Availability of young beef cattle is more seasonal according to typical production cycles.

Auction or sale barns are not appropriate sources for research ruminants. Many of these animals are culls of unknown genetics and poor health status. Selection of animal suppliers should be made only after research needs have been carefully considered. It is best to buy directly from as few sources as possible. Certain types of research (e.g., agricultural nutrition studies) may better be served by selecting animals from local agricultural suppliers rather than commercial vendors located in a different geographical area. Selection considerations for sources for research ruminants include flock or herd record keeping; health monitoring, vaccination, biosecurity, and preventative medicine programs; production standards and management practices consistent with the industry; vermin and insect control measures (especially flies and other flying insects); rearing programs and condition of young stock; and animal housing facilities.

Cattle used for research should be prepared with an appropriate transitional diet and vaccination program

('backgrounding'). Preliminary and periodic visits to the source farms should be conducted. It is important to establish a good relationship with local attending large animal veterinarians who will be valuable resources for current approved therapies and practices. Creative ways can be used to initiate and foster a good working relationship between the agricultural supplier and the research facility. Supplying vaccines or dewormers required for flock health programs, providing services such as quarterly serological testing or fecal examinations for the herd or flock, and paying a premium (above market price) for animals that meet desired quality research criteria are often helpful ways to manage this relationship.

A set of testing standards can be developed based on one high-quality supplier. Then flocks or herds can be 'qualified' by testing either a percentage of the herd or flock, or the entire flock or herd, for relevant infectious agents. The testing regimen itself should be carefully developed and evaluated for each source and research program need. Once qualified, each source farm should be re-evaluated periodically to maintain its status. Slaughter checks, necropsy of sentinel animals, or other screening tests may be required. Vaccination and deworming regimens should be instituted. Quarantine is advisable when animals arrive at the research facility. The animal screening process also depends on the origin of the animal (state, country) and the scientific program. Federal and State regulations must be followed.

Several texts on industry standards for flock or herd management provide a helpful orientation to those unfamiliar with ruminant husbandry and health care. These references also provide information regarding vaccination products licensed for use in ruminants as well as typical herd and flock vaccination and/or parasite control schedules. These texts are listed under 'Major references' at the end of this chapter (Anderson and Rings, 2009; Smith, 2009; Smith and Sherman, 2009).

When designing a vaccination program during qualification either at the source or at the research facility, it is important to evaluate the local disease incidence, the potential for exposure, and the cost effectiveness of vaccination. Labor and vaccine expenses may be much higher than the potential animal morbidity or mortality for diseases in a particular locality. Not all of the vaccines mentioned below will be necessary in all herds or flocks.

Typical health screening programs for sheep may include testing for Q Fever (*Coxiella burnetii*); contagious ecthyma; caseous lymphadenitis (*Corynebacterium pseudotuberculosis*); Johne's Disease (*Mycobacterium paratuberculosis*); ovine progressive pneumonia; and internal and external parasitism. For goats, screening might include Q Fever (*Coxiella burnetii*), caprine arthritis and encephalomyelitis (CAE), brucellosis, tuberculosis, and Johne's Disease (*Mycobacteria paratuberculosis*). Goats may also be tested for caseous lymphadenitis, contagious ecthyma, or mycoplasma as needed. The supplier should be queried about the vaccination program; at a minimum, vaccinations should include tetanus toxoid and other clostridial diseases. Because of the limited number of biologics approved for small ruminants, products licensed for cattle have been used with success in sheep, and some licensed for sheep are used in goats (American Association of Small Ruminant Practitioners, AASRP, 1994; Council Report, 1994). In some cases, approved feed additives, such as coccidiostats, are fed to sheep.

Depending on source, cattle may be screened for Johne's disease, brucellosis, tuberculosis, persistent infection with bovine viral diarrhea virus (BVDV), respiratory diseases, internal and external parasitism, and foot conditions such as hairy heel warts or foot rot. Determination of herd status with bovine leukosis virus (BLV) may be critical to some research endeavors. Vaccination programs should include BVDV, infectious bovine rhinotracheitis virus (IBR), bovine respiratory syncytial virus (BRSV), bovine parainfluenza-3 (PI-3), and *Leptospira* spp. Other vaccination programs, dependent on herd status, endemic diseases, or geographic location, may include immunizations against venereal diseases, clostridial diseases, pathogens causing neonatal diarrhea or respiratory disease, *Moraxella bovis* (pinkeye), *Fusobacterium necrophorum* (footrot), *Staphylococcus aureus* (mastitis), *Histophilus somni*, or rabies.

Transportation of animals from the source to the research facility must be carefully planned and coordinated, and all applicable livestock travel regulations must be followed. If commercial haulers are used, disinfection of trucks, trailers, and associated equipment (i.e., ramps and chutes) beforehand is particularly important. The loading, footing, distribution of animals within the trailers or trucks, and environmental conditions during shipping are important areas to evaluate so that stress or injury to animals is minimized or eliminated. Sufficient time for acclimation to the new facility, pen, handler, feed, and water must be allowed post arrival at the destination (Grandin, 2007).

D. Summary of Laboratory Management and Husbandry

Many recent publications address facility, husbandry and space requirements and standard husbandry practices for research and production ruminants. The United States Department of Agriculture (USDA) regulates the use of farm animal species used in biomedical and other nonagricultural research Code of Federal Regulations (CFR), 1985. The *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (i.e., the FASS 'Guide') and the *Guide for the Care and Use of Laboratory Animals* (i.e., the ILAR 'Guide') provide additional information to supplement the existing Animal Welfare Act

regulations (FASS, 2010; Hays *et al*., 1998; NRC, 2011; USDA, 2011).

Handler training and facility modification should be considered when appropriate to minimize stress in the husbandry and handling of ruminants. Stress decreases feed intake and affects growth and development in younger animals and reproductive performance in adults. Standard husbandry practices such as weaning, castration, dehorning, vaccinations, deworming or treatments for external parasites, shipping with the associated feed and water deprivation, introduction to new housing environments and novel personnel, and intercurrent disease are all stressors (Houpt, 2010). Animals should be acclimated to the use of halters, and other handling equipment (i.e., chutes and head gates) associated with the research program and personnel must be trained in appropriate handling techniques. Appreciation for ruminant behavior has grown in recent years resulting in refinement of ruminant handling techniques (Houpt, 2010; Grandin, 2007).

When ruminants are confinement housed, proper ventilation is critical. Ammonia buildup and other waste gases may induce respiratory problems. In cold weather, if the ceiling, walls or water pipes condense water vapor, the ventilation should be increased at the expense of lower temperatures. Adult goats and younger cattle are quite comfortable in colder temperatures if provided adequate amounts of dry dust-free bedding and draft protection. Sheep, because of their wool, are remarkably tolerant to both hot and cold extremes. Newborn lambs and recently shorn adults are susceptible to hypothermia, hyperthermia, and sunburn. Therefore, in outside housing areas, sheep should be provided with shelters to minimize exposure to sun and inclement weather.

Animals housed under intensive confinement conditions must be kept clean by daily removal of excreta from pens or enclosures. Feed and water equipment should be maintained in sound, clean condition and should be constructed to prevent fecal contamination. Waterers should not create a muddy environment in paddocks or pens and sufficient access to waterers provided to prevent competition or fighting. Feeders should be constructed according to species size and feeding characteristics and should prevent entrapment of head and limbs. Pens, passageways, chutes, and floors must be sturdy to withstand factors such as frequent cleaning as well as the strength, weight and curiosity of all ages of animals, especially the investigative and climbing behaviors of goats. Chain-link fences are dangerous because goats (as well as some breeds and ages of sheep) are curious and tend to stand on their hind legs against fencing or walls. Forelimbs may be caught easily in the mesh. Floors in any area where animals will be housed, led or herded must ensure secure footing to prevent slipping injuries. Ruminants are social herding animals and should be housed in groups, or minimally within eyesight and hearing of other animals. Singly housed animals must have regular human contact. Durable environmental enrichment items should be supplied to those animals that are housed in confinement. Singly housed or recently weaned calves, in particular, need play objects (FASS, 2010; Morrow-Tesch, 1997).

Photoperiod must be considered because sheep and goats are sensitive to changes in light cycle (especially reproductive parameters). Normally, sheep and goats should be maintained on a cycle comparable to natural conditions. Light intensity should be maintained at about 220 lux (ILAR, 1996; FASS, 2010). Light cycles can be manipulated for experimental reasons.

II. BIOLOGY

A. Unique Physiological Characteristics and Attributes, with Emphasis on Comparative Physiology

The development of the digestive system, including the unique function of the rumen, is among the most notable comparative anatomic and physiologic characteristic of ruminants. These species have a three-compartment forestomach (rumen, reticulum, and omasum) and a true stomach (abomasum). The mature rumen functions as an anaerobic fermentation chamber in which the enzymes, such as cellulase, of the resident bacteria (10^9–10^{10}/ml), allow the animal to prosper as an herbivore. Digestion is also aided by other microorganisms, such as protozoa (10^5–10^6/ml) and fungi, which contribute to the rumen ecosystem. The result is the production of volatile fatty acids (VFA: acetic, propionic, and butyric). Unlike the monogastrics, fermentative digestion and VFA absorption also occur in the large intestines. These VFA serve as the main sources of energy for ruminants rather than glucose. Glucose is formed from propionic acid (or from amino acids) for metabolism in the central nervous system, uterus, and mammary gland. Plasma glucose is much lower and regulated differently in ruminants than in nonruminants. Rumen microorganisms also synthesize B-complex vitamins and vitamin K, and provide protein utilized by the animals' systems. Large amounts of fermentation gases such as carbon dioxide and methane are naturally eructated (Jurgens *et al*., 2013; Reece 2004). Sheep and goats have tidy 'pelleted' dark-green feces. Cattle have pasty, moist, dark-green–brown feces.

Intestinal immunoglobulin absorption in neonates is crucial to the success of passive transfer. This transfer mechanism is functional for approximately the first 36 h after birth. Neonatal ruminants are immunocompetent, and this advantage is utilized when vaccinating calves

TABLE 15.2 Normal Values for Sheep, Goats, and Ruminants: Vital Signs, Life Spans, and Weights

Parameter/species	Sheep	Goats	Cattle
Chromosome number	54	60	60
Body temperature (°C) young	39.5–40.5	39–40.5	39–40.5
Body temperature (°C) adult	39–40	38.5–39.5	38–39
Heart rate (beats/min) young	140 (120–160)	140 (120–160)	120 (100–140)
Heart rate (beats/min) adult	75 (60–120)	85 (70–110)	60 (40–80)
Respiration rate young (breaths/min)	50 (30–70)	50 (40–65)	48 (30–60)
Respiration rate adult (breaths/min)	36 (12–72)	28 (15–40)	24 (12–36)
Life span (years)	10–15	8–12 years	20–25
Body weights (lbs)			
Birth	3–25		
1 month		25	
3 months		55	400
6 months	110	85	
9 months		110	
12 months		130	720
18 months		155	
24 months	300 (ram)	170	1100
	200 (ewe)		
36 months		205	
Deciduous dental formula	(for sheep, goats, and cattle)	2 (Di 0/3 Dc 0/1 Dp3/3)	=20
Permanent dental formula	(for sheep, goats, and cattle)	2 (I 0/3 C0/1 P 3/3 M 3/3)	=32

Vital sign data for goats is from (Smith and Sherman, 2009). Sheep weight data represent weights of feeder lamb and adult dry ewe (FASS, 2010). Goat weight data is for a large breed male goat. Cattle weight data represent weights of female Holstein or Guernsey dairy cattle (FASS, 2010). Life span data for sheep and cattle is from Brooks *et al.*, 1984.

against some common neonatal or juvenile diseases when the dams' colostrum is lacking antibody against those pathogens.

Three major ovine histocompatibility classes have been identified and are designated as OVAR (Ovis aries) Class I, II, and III (Franz-Werner *et al.*, 1996; Gao *et al.*, 2010). Bovines have several unique aspects of their immune systems. The bovine lymphocyte antigen system (BoLA) ranks after the human (HLA) and murine (H-2) systems in terms of depth of knowledge (Lewin, 1996). The complexity of the immunobiology of the bovine mammary gland is being studied extensively because mastitis is the most prevalent disease in the dairy industry. Several innate immune mechanisms and cellular defenses, and their variation throughout lactation, have been described (Sordillo and Streicher, 2002).

Bovine corneal epithelium is distinguished from other species because of its ability to heal without treatment, even when severely infected. Corneal ulcers are uncommon in sheep or goats.

B. Normal Values: Growth, Longevity, Hematology, Clinical Chemistry

Hematology and clinical reference texts are available for the ruminant species and include overviews of normal values, ranges, and discussions of the influence on the hemogram of many metabolic, nutritional, and other variables (Kaneko *et al.*, 1997; Weiss and Wardrop, 2010). These references should be consulted when preparing to include blood collection data in research protocols and when reviewing hematologic findings. Most veterinary diagnostic laboratories have also developed databases for normal ranges for hematologic and clinical chemistry values based on subjects from their service areas. Appropriate control groups must be incorporated into each research plan to establish the normal values for the particular locale, diagnostic facilities, breed, and so on.

Normal vital sign, life span, and weight values for sheep, goats, and ruminants are presented in Table 15.2.

TABLE 15.3 Normal Values, Hematology

Parameter	Sheep	Goat	Cattle
PCV (%)	27–45	22–38	24–46
Hgb (g/dl)	9–15	8–12	8–15
RBC ($\times 10^6$/μl)	9–15	8–18	5–10
WBC ($\times 10^3$)	4–12	4–13	4–12
Total Protein (g/dl)	6.0–7.5	6–7.5	7–8.5
MCV (fl)	28–40	16–25	40–60
MCH (pg)	8–12	5.2–8	11–17
MCHC (g/dl)	31–34	30–36	30–36
Reticulocytes (%)	0	0	0
RBC diameter (μm)	3.2–6	2.5–3.9	4.8
RBC life (days)	140–150	125	160
M:E ratio	0.77–1.68:10	0.69:10	0.31–1.85:10
Platelets ($\times 10^3$/μl)	250–750	300–600	100–800
Fibrinogen (mg/dl)	100–500	100–400	300–700
WBC Diff	Absolute count/μl (% of total)		
Stabs, Bands	Rare	Rare	0–250 (0–2)
Segs	400–6000 (10–50)	1200–6250 (30–48)	600–5400 (15–45)
Lymphs	1600–9000 (40–75)	2000–9100 (50–70)	1800–9000 (45–75)
Monos	0–750 (0–6)	0–550 (0–4)	80–850 (2–7)
Eos	0–1200 (0–10)	50–1050 (1–8)	80–2400 (2–20)
Basos	0–350 (0–3)	0–150 (0–1)	0–250 (0–2)
Coagulation tests (s)			
PT	13.5–15.9	9.0–14.0	6.8–8.4
PTT	27.9–40.7		11.0–17.4
TT	4.8–8.0	20.9–33.4	4.3–7.1

Normal hematologic and clinical biochemistry data is presented in Tables 15.3 and 15.4.

Ruminants generally have fewer neutrophils than lymphocytes. Blood urea nitrogen (BUN) values cannot be used as an indicator of renal function due to the metabolism of urea nitrogen by rumen microflora. Because of the large volume of rumen water, adult ruminants can generally go several days without drinking before significant dehydration occurs. Erythrocytes may become more fragile during rehydration, resulting in some degree of hemolysis and hemoglobinuria. However, severe dehydration can occur quickly in animals that are ill, particularly in pre-ruminant neonates. Urine pH is generally alkaline in adult ruminants.

Ruminant erythrocytes are smaller and more fragile than those of most other mammals; hematocrits tend to be overestimated unless blood samples are centrifuged for extended periods of time. Rouleaux formation does not occur in cattle, but does occur to a limited extent in sheep and goats. Normal caprine erythrocytes lack central pallor because they are flat and lack biconcavity, but they may exhibit poikilocytosis. In addition to fetal hemoglobin, sheep are reported to have at least six different hemoglobins. Sheep blood coagulation is similar to that of humans. At least seven blood group systems have been identified in sheep (A, B, C, D, M, R, and X) and at least five in goats (B, C, M, R-O, and X) (Rychlik and Krawczyk, 2009; Cornell Animal Health Diagnostic Center http://ahdc.vet.cornell.edu/clinpath/modules/coags/typeoth.htm). Because transfusion reaction rates may be as high as 2–3%, cross-matching is advisable, although not always practical (Smith, 2009). Blood may safely be obtained in volumes of 10 ml/kg body weight, and given in volumes of 10–20 ml/kg.

TABLE 15.4 Normal Values, Clinical Biochemistry

Parameter/species	Sheep	Goat	Cattle
Alanine aminotransferase (ALT, GPT; U/l) s, hp	30 ± 4	6–19	11–40
			(27 ± 14)
Albumin (g/l)	24–3.0	27.0–39.0	30.3–35.5
	(27 ± 1.9)	33.0 ± 3.3)	(32.9 ± 1.3)
Alk. phosphatase (AlkP, U/l)	68–387	93–387	0–488
	(178 ± 102)	(219 ± 76)	(194 ± 126)
Aspartate Aminotransferase (AST, GOT; U/l) s, hp	60–280	167–513	78–132
	(307 ± 43)		(105 ± 27)
Bicarbonate (HCO_3, mmol/l)	20–25		17–29
Bilirubin, conjugated (mg/dl) s, p, hp	0–0.27		0.04–0.44 (0.18)
	(0.12)		
Bilirubin, unconjugated (mg/dl)	0–0.12		0.03
Bilirubin, Total (Tbili, mg/dl)	0.1–0.5	0.01	0.01–0.5
	(0.23 ± 0.1)		(0.2)
Blood urea nitrogen (BUN; mg/dl) s, p, hp	8–20	10–20	20–30
		(15 ± 2.0)	
Calcium, total (mg/dl) s, hp	11.5–12.8	8.9–11.7	9.7–12.4
Carbon dioxide, Total (mmol/L) s, hp	21–28	25.6–29.6	21.2–32.2
	(26.2)	(27.4 ± 1.4)	(26.5)
Chloride (Cl; mmol/L) s, hp	95–103	99–110.3	97–111
		(105.1 ± 2.9)	(104)
Creatine kinase (CK) U/l s, hp	8.1–12.9	0.8–8.9	4.8–12.1
	(10.3 ± 1.6)	(4.5 ± 2.8)	(7.4 ± 2.4)
Creatinine (mg/dl) s, p, hp	1.2–1.9	1.0–1.8	1.0–2.0
Gamma glutamyltransferase (GGT; U/l) s, p	20–52	20–56	6.1–17.4
	(33.5 ± 4.3)	(38 ± 13)	(15.7 ± 4.0)
Globulin (g/l) s	35.0–57.0	27.0–41.0	30.0–34.8
	(44.0 ± 5.3)	(36.0 ± 5.0)	(32.4 ± 2.4)
Glucose (mg/dl) s, p, hp	50–80	50–75	45–75
	(68.4 ± 6.0)	(62.8 ± 7.1)	(57.4 ± 6.8)
Lactate dehydrogenase (U/l) s, hp	238–440		692–1445
	(352 ± 59)		(1061 ± 222)
Magnesium (mg/dl) s	2.2–2.8	2.8–3.6	1.8–2.3
Phosphorus (P; mg/dl) hp	5.0–7.3	4.2–9.1	5.6–6.5
	(6.4 ± 0.2)	(6.5)	
Potassium (K; mmol/l) hp	3.9–5.4	3.5–6.7	3.9–5.8
	(4.8)	(4.3 ± 0.5)	(4.8)
Sorbitol dehydrogenase (SDH; U/L) hp	5.8–27.9	14.0–23.6	4.3–15.3
	(15.7 ± 7.5)	(19.4 ± 3.6)	(9.2 ± 3.1)
Sodium (Na; mmol/l) hp	139–152	142–155	132–152
		(150 ± 3.1)	(142)
Total protein (TP, g/l) s	60.0–79.0	64.0–70.0	67.4–74.6
	(72.0 ± 5.2)	(69.0 ± 4.8)	(71.0 ± 1.8)

Clinical biochemistry data from Kaneko et al. (1997).
Data presented as ranges with mean and standard deviation in parentheses. S = serum; p = plasma; hp = heparinized plasma.

In general, aspartate amino transferase (AST) and lactate dehydrogenase (LDH) are not liver specific in ruminants, and alanine amino transferase (ALT) cannot be used to evaluate hepatic disease in goats. Gamma glutamyl transferase (GGT) and alkaline phosphatase (AP) are associated with biliary stasis, and elevations in GGT are generally associated with hepatic damage.

C. Nutrition

The nutritional needs of ruminants vary considerably according to the species, breed type, age, physiologic state, and environment. For example, mineral and other nutritional requirements vary even among breeds of cattle. Several references are available that describe the varying requirements and nutrient content of common feedstuffs (National Research Council (NRC), 2000, 2001, 2007; Smith, 2009). Computer programs are readily available for those who may need to formulate and balance rations.

Pre-formulated commercial feeds, concentrates, and supplements are available for the different species and production classes of ruminants. Often these are used as supplements for pasture, hay, and/or other forages. Concentrate mixtures typically contain a protein source such as soybean meal; salt and other required macro- and microminerals; and vitamins A, D, and E. Palatability of feeds should be taken into account. Mineral deficiencies and supplementation can influence several physiologic parameters such as reproduction and immune function. Whenever possible, introduction of new stock to a research facility should include continuation of the source feeding program followed by gradual transition to appropriate local feedstuffs (NRC, 2000, 2001, 2007).

Good-quality pasture meets the nutritional requirements for maintenance and growth of ruminants under many circumstances. However, lush spring pastures, especially pastures containing alfalfa, can induce bloat, diarrhea, grass tetany, or nitrate poisoning. Ruminants not acclimated to lush pasture should be fed good-quality hay and slowly introduced to those pasture environments.

When ruminants have access to pasture, it is important to be aware of different eating habits. Sheep and cattle are grazers. Goats are browsers and will readily eat not only grasses, but also seeds, nuts, fruits, and woody-stemmed plants. Since goats are selective eaters, they tend to consume the leafy or more nutritious parts of the plant and often require no grain supplementation (Bretzlaff *et al.*, 1991). If needed, pelleted concentrates are preferred because the goat will pick out large particles in mixes. When given access to a salt block, ruminants will generally self-regulate intake. Horse and sheep feeds may be fed to goats; sheep are susceptible to copper toxicity and should not be fed supplements formulated for horses. Goats will consume 5–8% of body weight in dry matter intake (whereas cattle will usually consume only 4% of body weight).

Rations that contain excessive phosphorus, a low calcium–phosphorus ratio, or elevated magnesium levels may induce urinary calculi in male ruminants. Calculi may also develop when forage grasses are high in silicates and oxalates. Ideally, roughage sources should be analyzed for nutrient content and supplements formulated which provide a nutrient profile complementary to available forage.

To increase ovulation rate in does and ewes, some producers 'flush' females by feeding 200–400 g of concentrate per head per day for several weeks before and after the initiation of the breeding season. Thin pregnant does and ewes should receive supplemental grain and *ad libitum* forage during the last 6 weeks of gestation.

All newborn ruminants must receive passive immunity from colostrum, the first postpartum milk of a dam. Colostrum contains concentrated maternal antibodies (mostly as IgG1), functional leukocytes, and cytokines. The quality of the colostrum is affected by vaccination programs and the dam's overall condition and nutrition throughout gestation and at the time of parturition. Ensuring effective passive immune transfer primarily is dependent on the timing and volume of colostrum ingested by the neonate. Reliance on suckling in dairy calves has been associated with failure of passive immune transfer (NAHMS Dairy Studies, 2007). Frozen or 'banked' colostrum may be used for animals whose dams have poor quality or inadequate volume of colostrum. Colostrum immunoglobulin content can be estimated by specific gravity, by a Brix refractometer, or by commercial test kits designed for on-farm use (Brujeni *et al.*, 2010). Commercial colostrum replacers or supplements also are available. A Holstein calf should receive its first 2-l meal of colostrum within 4 h of birth and should consume at least 100 g of IgG within the first 24 h of life. In general, this IgG requirement can be met with 4 l of good-quality colostrum. After 2–3 days, dairy calves are fed milk replacer or whole milk. Due to infectious disease concerns, waste milk should not be fed to calves unless it has been pasteurized.

Commercially available milk replacers that provide complete nutrition for the neonate are available for the common livestock species and should be prepared and fed according to the manufacturer's recommendations. Containers used to prepare and feed these replacers should be sanitized after each feeding. In agricultural settings, calves housed either outside or in cold housing must receive additional calories (milk or milk replacer) when ambient temperatures fall below the thermo-neutral zone.

Young ruminants can be offered good-quality hay to nibble on by 1 week of age. Rumen development in calves has been shown to be enhanced by supplementation with

TABLE 15.5 Reproductive Parameters for Ruminants

Species	Age at puberty (months)	Cycle type	Duration of cycle (days)	Length of estrus (hours)	Gestation (days)
Cattle	4–18 (mean 12)	Polyestrus	18–24 (21)	10–24 (mean 18)	270–292
Sheep	7–8	Seasonally polyestrus	14–19 (mean 17)	24–30	147–150
Goat	4–8	Seasonally polyestrus	18–24	24–96 (mean 40)	144–155

a concentrate feed (Davis and Drackley, 1998). Commercial 'starter' feeds with appropriate levels of energy and protein should be fed according to the manufacturer's recommendations by 2–3 weeks of age. Young animals should have access to fresh water, if not continually, then offered at least twice daily. Lambs and beef calves typically are fed a 'creep' supplement to provide additional nutrients and accustom them to solid feed prior to weaning.

D. Biology of Reproduction

Several useful references addressing ruminant reproduction in detail are available. These references are available in the back of this chapter under 'Major references' (Anderson and Rings, 2009; Smith, 2009; Youngquist and Threlfall, 2007; Hafez and Hafez, 2000).

1. Reproductive Physiology

Sheep and goats are seasonally polyestrus with estrus (heat) brought about by decreasing day length. Some breeds of sheep may cycle both in the fall and spring. In a research environment, ewes can be artificially stimulated to progress from anestrus to estrus cyclicity by maintaining the females in 8 h of light and 16 h of dark for 8–10 weeks. Older ewes tend to have multiple lambs, and Finn and Dorset breeds are especially prolific. Does also can bear singles, twins, or triplets.

The reproductive physiology and management of cattle are addressed in detail in texts and references oriented toward herd and production management (Anderson and Rings, 2009). Cows usually bear single calves, although twin births do occur. When twins are combinations of male and female calves, the female should be evaluated for freemartinism (see below under 'sexing'). Reproductive parameters for ruminants are given in Table 15.5.

2. Detection of Estrus and Pregnancy

Typically, ewes in heat will show a mild enlargement of the vulva with slight increases of mucus secretion. Ewes may isolate from the flock and appear anxious. It is most reliable to employ the help of a sterile ram to mark females when they are in standing heat. Ewes may be 'hand mated,' in which they are placed either singly or in small groups with the ram of choice and removed as serviced, or 'group mated' in which a mature ram is placed with 50–60 ewes for the entire 6-week breeding season. In either mating system, it is best to attach a marking harness to the male so that individual ewes can be identified as serviced.

Transabdominal ultrasound or interrectal Doppler probes are used for pregnancy detection: accuracy is generally best beyond 60 days of gestation. Commercial tests for serum pregnancy-specific protein B can confirm pregnancy beyond approximately day 30 in sheep and goats.

Signs of estrus in goats include uneasiness, tail switching or 'flagging,' redness and swelling of the vulva, clear vaginal discharge that becomes white by the end of estrus, and vocalization. Does can be induced to show signs of heat by buck exposure, and will ovulate within 7 to 10 days after introduction of the buck. Most goats ovulate between 24 and 36 h after the onset of estrus and should be mated once signs of estrus are recognized and every 12 h until the end of estrus. Once bred successfully, a goat will only rarely show signs of heat again. Pregnancy can be confirmed similarly to sheep. Dairy goats should have at least a 6- to 8-week dry period for the udder to fully involute and prepare for the next milking period.

The hallmark of estrus in the bovine is standing to be mounted by another animal, a behavioral sign of estrus which lasts approximately 12–16 h with a range of 6–24 h (Smith, 2009). A clear vaginal mucous discharge is a secondary sign of estrus. Ovulation occurs 12–18 h after the onset of estrus. Detection of estrus is usually accomplished by visual observation of mounting behavior by other females (i.e., the cow standing to be mounted is the individual in estrus) or receptivity to a bull (willingness to stand). Teaser animals outfitted with marking devices are also used. Other methods of detecting estrus include monitoring blood progesterone levels, change in conductivity of cervical mucus, change in vaginal pH and body temperature, and evaluating activity levels by the use of pedometry (Hafez and Hafez, 2000).

In the cow, as in small ruminants, presumptive diagnosis of pregnancy can be inferred by failure to return to estrus. Real-time ultrasonography can be used to

determine pregnancy as early as 28–32 days after insemination. Fetal gender can also be determined by experienced personnel using this method by about day 55. Pregnancy also can be diagnosed by 30–40 days post conception by palpation per rectum. Levels of bovine pregnancy-specific protein B may also be measured using one of several commercial tests for serum or milk.

Placentation in sheep, goats, and cattle is epitheliochorial and cotyledonary. The placentomes, the infolded functional units of the placenta, are formed as the result of fusion of the villi of the fetal cotyledons projecting into the crypts of the maternal caruncles (specialized projections of uterine mucosa). Caruncles of sheep and goats are concave in shape while those of cows are convex. In all three species, placentomes are distributed between the pregnant and nonpregant horns of the uterus, athough the placentomes in the nongravid horn will be smaller than in the gravid horn.

3. *Husbandry Needs*

Pregnant dams must have a proper plane of nutrition (not overnutrition) and adequate exercise. The dam should be confined to a small pasture or sanitized maternity pen a few days to hours prior to parturition. The birthing environment will be very important in the overall health of the dam and offspring. Outdoor parturition in a small birthing pasture has advantages. There is less stress and intensity of pathogens. Indoor maternity pens should be clean, dry, well bedded, well ventilated and well lit. Management of these pens is important to minimize pathogens to which dam and young are exposed. Water troughs or buckets should be elevated or placed outside the pen because lambs and kids have a tendency to fall or be pushed into them. Between dams, the area should be cleaned, sanitized and allowed to dry, and fresh bedding installed for the next occupant. Moving the female immediately before or during parturition may delay the birthing process. Dams should be monitored closely during parturition for dystocia which may result in dead or severely weakened offspring from the prolonged birthing process.

Prior to parturition, the tail and perineal area of ewes and does should be clipped and cleaned. The pregnant doe or ewe needs approximately 1.4–1.5 m^2 of area for the birthing process. Each cow should have a minimum pen area of 9 m^2. Evaluation of a cow's udder as parturition approaches is important in order to ensure adequate passive transfer to the neonate. In the case of dairy cows, young calves are often hand-fed colostrum rather than being allowed to nurse from the dam. Inexperienced heifers may react indifferently or aggressively to their offspring and should be monitored more closely than older, multiparous cows with uneventful calving histories.

4. *Parturition*

Ewes approaching parturition generally isolate themselves from the flock, become restless, stamp their feet, blat, and periodically turn and look at their abdomen. The pelvic region will appear relaxed and milk will be present in the udder. Once hard labor contractions begin, lambs will usually be born quickly. Animals that don't appear to be progressing in labor should be examined for dystocia. Most cases of fetal malpresentation can be corrected via vaginouterine manipulation. Occasionally caesarean sections will be necessary. Sanitation, cleanliness, and adequate lubrication are of utmost importance when performing obstetrical procedures in all ruminant animals.

Does nearing parturition have an obviously swollen udder and red swollen vulva. Pelvic ligaments at the base of tail relax. Approximately 24 h prior to birth, rectal temperature will drop slightly below normal. Signs of impending parturition include restlessness; vocalization (bleating softly); uneasiness including getting up and down, pawing and bedding; and, a mucous discharge leading to a moist tail. Most goats prefer to kid alone and do so unaided. However, if labor is prolonged for more than 1 h, a vaginal exam is indicated. Many large dairy goat facilities attempt to control the onset of parturition in order to assist birthing. The drug of choice to induce parturition in the goat is prostaglandin $F_{2\alpha}$ (PGF2α) (Ott, 1982). On day 144 of gestation, goats given PGF2α (2.5–5 mg) will deliver kids within 28–57 h. Prostaglandins and glucocorticoids also can be used to induce parturition in the bovine.

The goat is one of the few ungulate species that commonly exhibit 'false pregnancy,' or pseudopregnancy. Does may have characteristically distended abdomens, may develop hydrometra and 'deliver' large volumes of cloudy fluid at expected due dates. Subsequent pregnancies can be normal. Prostaglandin use has been successful in treating false pregnancy.

At the time of calving, cows will separate themselves from the rest of the herd. A cow will lift her tail and arch her back when she is within a few hours of delivering the calf, and most are recumbent during delivery. Typically, the whole birthing process takes about 100 min. The length of labor of cows carrying larger calves or in primiparous animals will be longer. If animals are disturbed, labor may be delayed.

All postparturient animals should be monitored for successful delivery of the fetal membranes within 12 h of birth. If fetal membranes are not expelled, the dam should be monitored daily for temperature, attitude, and appetite. It is not recommended that the placenta be manually removed or that intrauterine boluses be placed in the uterus. Cows and sheep occasionally eat placentas which may subsequently obstruct rumen outflow

and require surgical correction. Remove membranes that have been passed to prevent ingestion.

5. Early Development of the Newborn

Many neonatal ruminants will not need much assistance following birth. Dams are usually attentive to their young and will clean their offspring by licking, stimulating them to breath and to rise. When human assistance is given, the newborn's nose and mouth should be wiped free of secretions; gently swinging the animal, head down, aids in removal of these fluids. The neonate should be dried off and stimulated through rubbing to aid its breathing and the navel should be dipped in an iodine solution to prevent subsequent navel infections. Young may be identified by the application of an ear tag or ear notch. It is extremely important that all neonatal ruminants be supplied with high-quality colostrum within the first 12–24 h of birth. Young that are not nursing on their own should be tube fed with colostrum that has been collected and saved previously (i.e., frozen), or collected from the mother after parturition. Kids and lambs may require supplemental heat (as from a heat lamp) during cold weather.

To control transmission of infectious diseases such as CAE or Johnes' disease, young ruminants may be removed immediately from the dam and hand-fed heat-treated colostrum. The first feeding can be up to 125 ml of colostrum (lambs and kids) or up to 4 l (calves). Milk fed can be reduced by 4 weeks by decreasing either the volume fed or the number of feedings.

Kids should be dehorned and castrated within the first few days of life. Due to the thin calvarium and relatively small frontal sinus in goat kids, electric or butane dehorners should be used with great caution to avoid heat damage to the cerebral cortex. Dehorning of calves is performed when hornbuds appear (3–6 weeks) and castration is performed between 2 and 9 weeks of age or later. Sedation, local anesthesia, and post-procedural analgesia (generally NSAIDs) are appropriate for dehorning and castration procedures.

6. Sexing

Sexing the young in any of the ruminant species is straightforward. The vulva of the female young is located just ventral to the anus. The genitalia of the male include a penis located along the ventral midline and a scrotum located in the inguinal region. The phenomenon of 'freemartin,' a genetic female born as a twin to a male, is the result of anastomoses between placental circulations of the twin fetuses, with mixing of blood-forming cells and germ cells, resulting in XX/XY chimeras. This occurs in 85–90% of phenotypic bovine females born twin to males. The female will often have an abnormal vulva and clitoris and the vagina will be a blind end due a lack of a cervix. Sometimes singleton freemartins are born if the male fetus is lost after 30 days gestation. Multiple births are selected for and are common in sheep; but the freemartin phenomenon is regarded as rare in this species. Twinning is common in goats and freemartinism occurs in about 6% of male–female pairs of twins. Intersexes are seen in some goat breeds, and when polled goats are mated (see Section III, B, 1).

7. Weaning

Grain, and later roughage, should be offered to lambs well in advance of weaning so that they can adjust to the feedstuffs. To prevent the ewe from ingesting the lamb ration, a 'creep' can be set up in an area adjacent to the ewe/lamb pen by devising a slatted entry for the lambs to enter but not the ewes.

Lambs that are consuming 0.6–0.8 kg of creep feed per day may be weaned. Depending on the individual program, lambs may be weaned as early as 4 weeks of age; although, 6–8 weeks of age is more common. The lambs should be monitored after weaning to ensure that they continue to gain weight and are eating the new ration. Kids should be introduced to forages within the first week of life because the natural curiosity of these animals will cause them to investigate sources of feed. Hand-fed milk should be reduced by 4 weeks of age and kids can be weaned by 6–10 weeks or 18–25 pounds. Dairy calves are usually removed from their dams immediately after birth and fed milk replacer or whole milk until weaning at 4–7 weeks. Stressful procedures, such as castration, dehorning, and vaccinations should be avoided in the week prior to and following weaning.

Passive immunity provided by dams' colostrum decreases gradually until the young are about 6 months old. In calves, the duration of passive immunity varies considerably. Although vaccinations are not necessary during this time, calves have been shown to mount memory B and T cell responses to vaccination even in the presence of colostral antibody so it is not uncommon for calves to receive vaccinations at 4 months of age (Endsley *et al.*, 2003). Some producers choose to begin vaccinating calves at 1–2 months of age, and continue with monthly booster immunizations until the animals are 7 months old and passive immunity is no longer a possibility.

8. Artificial Insemination

AI is now an integral part of dairy herd management; natural insemination in dairy cattle is relatively rare. Technicians performing the AI technique are available through commercial enterprises, although on many dairy farms employees are trained to perform AI. Information regarding the storage and handling of the semen; and the skills and record-keeping is covered extensively elsewhere Youngquist and Threlfall, 2007). In sheep, AI is more difficult than in cattle. Laparoscopic AI

involves the surgical instillation of semen into the uterus through a small abdominal opening. The procedure has achieved as high as a 70% pregnancy rate with frozen semen (McCappin and Murray, 2011), but is technically involved and costly. Cervical AI involves the transvaginal introduction of semen into the cervix. A modification of this technique (Transcervical AI) allows for penetration through the cervix, into the uterus. This method (called the Guelph System for Transcervical AI) leads to successful penetration into the uterus in up to 75% of ewes when performed by an experienced inseminator.

9. Synchronization

Control of breeding in the goat has been studied mostly in dairy breeds in order to produce milk throughout the year and to reduce kidding labor. Goats in the luteal phase of the estrus cycle, days 4–16, are sensitive to $PGF_{2\alpha}$ (2.5–5 mg IM) and will show estrus in 36–60 h post injection (Youngquist and Threlfall, 2007). Pheromones may be utilized by introduction of the buck to a group of does, which will induce ovulation and may even synchronize does. Does that are kept separate from the buck will show signs of estrus, and ovulate within 6–10 days when introduced to a buck. Vaginal pessaries of fluorogestone acetate left in place for 21 days in the doe followed by an injection of pregnant mare serum gonadotrophin (PMSG) at the time of pessary removal also has proven successful.

Synchronization of cattle estrous cycles and superovulation are used in many dairy production settings where estrus synchronization and/or embryo transfer are advantageous to production and management. The options and dosing regimens are described in detail in veterinary clinical texts (Hafez and Hafez, 2000; Youngquist and Threlfall, 2007). One of the more common practices involves the use of products approved for use in cattle such as PGF2α or one of its analogs to induce luteolysis. Progestogens are also used in the form of vaginal suppositories. Another approach is to synchronize ovulation (OvSynch®) with scheduled delivery of PGF2α followed by gonadotropin-releasing hormone. Estrus may be suppressed in beef heifers in a feedlot setting by the feeding of melengestrol acetate, a synthetic progestogen.

Because sheep are hormonally similar to other ruminants, estrus synchronization techniques are comparable. Ewes may be exposed to vasectomized rams prior to the beginning of the normal fall mating period. Pheromones released from males naturally stimulate the females to cycle and to synchronize their heats. Artificial or natural progesterones can be administered in the feed, through parenteral injection, subcuticular implants and vaginal pessaries. Other synchronization methods using gonadotropins and prostaglandins have also been shown to be effective (Titi *et al.*, 2010).

10. Embryo Transfer

Embryo transfer involves the removal of multiple embryos from a superovulated embryo donor and transferring them to synchronized recipients. This method maximizes the genetic potential of the donor animal. The donor animal is superovulated with gonadotropins and inseminated. In sheep, embryos are surgically removed from the donor's uterus about 1 week after breeding. In cattle, the procedure is a nonsurgical transcervical flush of the uterus. About 75% of expected embryos (determined by counting corpora lutea) can be recovered; successful recovery is affected by factors such as age of the donor, reproductive health, and surgeon or technician expertise. Recipients are hormonally synchronized with the donor animals. On the day of embryo collection, transferable embryos are implanted into the uterus of the recipient using methods similar to AI. Pregnancy rates average about 70%. If recipients are not available, embryos, like sperm, can be frozen and kept for later transfer. Disease screening for all animals involved is important because several pathogens can be transmitted directly or indirectly, such as BVDV, bluetongue virus, infectious bovine rhinotracheitis virus, and mycoplasmal species.

11. Miscellaneous Management Considerations

a. Management of Male Animals

In sheep flocks and goat herds, as noted, male young are usually castrated by 1 month of age. The elastrator method is the more popular for animals less than 1 week of age. Other methods include crushing the spermatic cord with an emasculatome and surgical castration. The distress associated with castration and tail docking in lambs is the subject of debate and has been researched recently. The reader is referred to journal articles and the AVMA website regarding welfare implications (Stafford, 2007; AVMA, 2012). Bull calves should be castrated as early as possible, but no later than 3 month of age. In some production situations, however, where maximum hormone responsive muscle development and grouping animals together for procedures dictate scheduling, the procedure may be performed on older males with appropriate sedation and analgesia.

Breeding and vasectomized rams and bucks are usually maintained by medium to large production farms. Smaller farms often borrow breeding males. Vasectomized males are often retired breeders and should be tattooed or identified clearly. The vasectomy technique for both species is comparable (Smith and Sherman, 2009). Rams may be housed together for most of the year while bucks are penned separately.

Because ewes will only exhibit a limited number of estrous cycles before becoming reproductively quiescent, it is critical that the male be capable of successfully

breeding the female in an expeditious manner. Any defects in the external genitalia, reproductive diseases or musculoskeletal abnormalities may prevent successful copulatory behaviors. Furthermore, it is important to know the semen quality of the ram as one indicator of fertility. Semen can be collected via electroejaculation or by use of a teaser mount. Once semen is collected, it should be handled carefully and kept warm to prevent sperm death leading to improper conclusions about the male. Determination of sperm quality is based on volume, motility, sperm cell concentration, and morphology.

The extensive use of AI in the dairy cattle industry has minimized the use of bulls on many farms. Breeding bulls used in dairy operations should be monitored for excessive weight gain and for lameness due to laminitis, often a result of feeding bulls the relatively energy-dense diets used for dairy cows. The use of natural service is much more common in beef production systems. Breeding bulls must be part of the herd vaccination program, with special attention to appropriate timing of immunizations for the commonly transmitted venereal diseases, campylobacteriosis and trichomoniasis. During an intensive breeding season, providing an adequate number of bulls to service eligible cows is critical to breeding success.

Cattle tail docking is a relatively recent development in dairy herd management and practiced in the belief that it will minimize bacterial contamination of the udder and therefore the milk. Tails are typically docked to about 10 inches in length. To date, published research does not support this practice as a means of improving milk quality or cow cleanliness. Tail docking is a common husbandry practice in sheep. The reader is referred to the AVMA website regarding welfare implications (AVMA, 2012).

E. Behavior

Healthy ruminants have good appetites, are alert and curious, and move without hindrance. Even adult animals will play when provided sufficient space. Ruminants normally vocalize, and handlers will learn to recognize normal communication among the group in contrast to excessive, strained vocalizations which may be a sign of fear, anxiety or stress. 'Bruxism' or grinding of the teeth by a ruminant is usually associated with discomfort or pain. Other signs of discomfort, stress, or illness include decreased time spent eating and cud chewing, restlessness, prolonged recumbency with outstretched neck and head, and hunched back when standing. Unhealthy ruminants may be thin, may have external lumps or swollen joints, an unusual abdominal profile, or rough or dull coats.

All ruminants are herd animals and exhibit social behavior, therefore, every effort should be made to allow contact among individuals in terms of either direct contact, sound, smell, or sight. Sheep in particular are gregarious and should be handled as a group. Human contact and handling should be initiated promptly and maintained regularly throughout the animal's stay in the research facilities. Animals should be provided sufficient time to acclimate to handlers and research staff. Cattle and sheep can hear at higher frequencies than humans can and may react to sounds not perceived by handlers.

Movement of animals is simplified by proper facility design. Chutes should have solid walls and allow animals to follow a lead animal. Ruminants have a wide-angle visual field but are easily startled by activities taking place behind them. Animal movement often is disrupted by contrasts such as light and shadows impinging on a chute or corral. Livestock always should be moved slowly and calmly; handlers should avoid the use of prods, loud noises, or sudden movements. Ruminant animals have a flight zone (minimum zone of comfort) which when penetrated, will result in scattering of the herd or flock. This minimal flight distance can be modified by increasing handling of the animals and by working at the edge of the zone. Minimal flight distances should always be considered when working with animals in chutes, pens, or other confined areas.

Goats exhibit behavioral characteristics that make them quite distinct from other ruminants. Their browsing activity makes them quite orally investigative. Goats will readily nibble or chew just about anything they come in contact with so researchers should keep all paperwork and equipment out of reach. Goats are inquisitive, restless, agile jumpers and climbers, and quite mischievous. If maintained in paddocks, strong high fences are essential as are adequate spaces for exercise or boulders or rock piles for hoof maintenance and recreational climbing. Goats are more tolerant of isolation and are more easily acclimated to human contact than sheep and cattle. Goats with horns will use them to their advantage and horns may also become entangled in fencing. Although less strongly affected by flock behavior, goats are social animals. Most goats raised in close human contact are personable and cooperative and can easily be taught to stand for various procedures including blood collection.

Ruminants of all ages, especially cattle, should be handled with an appreciation of the potential for serious injury to human handlers that may result (Houpt, 2010). While dairy cattle have been bred and selected over centuries for docility, beef breeds are generally more difficult to handle and restrain. All cattle respond well to feed as a reward for desired behavior. Healthy cattle typically are very curious and watchful and are alert to sounds and smells. Because of ruminant digestive and metabolic needs, much of the day is spent eating or cud chewing. Isolation from other cattle, rough handling by attendants, and unfamiliar visual patterns, routines, or

environments are all sources of stress to cattle. These stressors increase the difficulty of handling and may exacerbate signs of systemic illnesses.

Estrous behavior in dairy cattle can be easily identified and a number of tools exist (pedometers, pressure sensitive transponders, dyes placed on cows' backs) to facilitate identification of this behavior. In addition to mounting or standing to be mounted, common estrous behaviors include decreased feed consumption, hyperactivity, flehmen, standing behind other cows resting their chins on their backs, licking, and sniffing.

Calves are known for non-nutritive suckling, bar licking, and tongue rolling. Non-nutritive suckling behavior is greater in hungry calves and also immediately after a milk meal. It is best to provide nipples and other clean noninjurious materials for the animals to suck. Non-nutritive suckling can be detrimental in group-housed calves since it can result in disease transmission particularly mastitis, and hairball formation. Environmental enrichment devices have been developed to cope with this behavior. The behavior diminishes as the animals are weaned on to solid food (Morrow-Tesch, 1997; Houpt, 2010).

Play activity and vocalizations of calves mimic adult dominance behaviors. Play activity by young adult cattle is more common in males, can be quite rough, and is often triggered by a change in the environment. Social hierarchies are established within a herd by dominance behavior; the presence of horns, increasing age and body size are important determinants of dominance. Aggression is most common among intact adult males.

III. DISEASES

This section focuses primarily on the more common diseases affecting sheep, goats, and cattle in the United States and North America and those that are reportable. For detailed information not included in this limited overview and for diseases of importance internationally, the authors recommend several excellent comprehensive and focused veterinary clinical texts and periodicals: these are listed under 'Major references' at the end of this chapter.

Several of the infectious diseases described herein are reportable to the USDA. The status of these diseases can change from month-to-month and vary by regions across the United States and the world. For up-to-date information on reportable livestock diseases and reporting procedures, veterinarians are encouraged to make use of online resources from both State and Federal animal health authorities, as reportable diseases may differ from state to state. The USDA/APHIS website (http://www.aphis.usda.gov/wps/portal/aphis/home) has abundant materials on program diseases (such as brucellosis and bovine tuberculosis), foreign animal diseases, and other diseases of interest, and also a directory of Area Veterinarians in Charge (AVICs).

Recommendations for current drug therapies, both approved and off-label use in ruminants, including withholding times prior to slaughter, formularies, and related information also can be found in the references noted above and formularies (Hawk and Leary, 2005; Plumb, 2011). In addition, the Food Animal Residue Avoidance Databank (FARAD), accessible on the Internet, should be used as a resource. FARAD is a food safety project of the USDA, and is an information resource to prevent drug and pesticide residues in food animals and animal products.

Extra-label drug use is defined by the Animal Medicinal Drug Use Clarification Act of 1994 (AMDUCA, 1994) as "Actual use or intended use of a drug in an animal in a manner that is not in accordance with the approved labeling. This includes, but is not limited to, use in species not listed in the labeling, use for indications (diseases and other conditions) not listed in the labeling, use at dosage levels, frequencies, or routes of administration other than those stated in the labeling, and deviation from labeled withdrawal time based on these different uses" (21 CFR 530, 1994). The FDA under the provisions of AMDUCA recognizes the professional judgment of veterinarians and allows the use of extra-label drugs *by veterinarians* within the context of a valid veterinarian–client relationship under certain conditions:

i. There is no approved new animal drug that is labeled for the intended use that contains the same active ingredient in the required dosage form and concentration.
ii. A veterinarian has made a careful diagnosis and evaluation of the condition.
iii. The veterinarian has established an extended withdrawal period prior to marketing.
iv. The identity of the treated animal is assured and maintained.
v. Ensure that no illegal drug residues occur in any food-producing animal subjected to extra-label treatment.
vi. The prescribed or dispensed extra-label drug must bear labeling information which is adequate to assure the safe and proper use of the product.

Note: Extra-label use is limited to circumstances when the health of an animal is threatened or suffering or death may result from failure to treat. Use of extra-label drugs for the purpose of enhancing production is prohibited. Additionally, the FDA can prohibit the extra-label use of a new animal drug if no sufficient analytical method exists for detection of residues and/or if the drug poses a risk to human health. The extra-label use

of the following drugs is prohibited *even if the criteria for extra label drug use has been met*.

1. Chloramphenicol;
2. Clenbuterol;
3. Diethylstilbestrol (DES);
4. Dimetridazole;
5. Ipronidazole;
6. Other nitroimidazoles;
7. Furazolidone;
8. Nitrofurazone;
9. Sulfonamide drugs in lactating dairy cattle (except approved use of sulfadimethoxine, sulfabromomethazine, and sulfaethoxypyridazine);
10. Fluoroquinolones;
11. Glycopeptides;
12. Phenylbutazone in female dairy cattle 20 months of age or older;
13. Cephalosporin (excluding cephapirin) use in cattle, swine, chickens, and turkeys:
    Using cephalosporin drugs at unapproved dose levels, frequencies, durations, or routes of administration is prohibited;
    Using cephalosporin drugs in cattle, swine, chickens, or turkeys that are not approved for use in that species (e.g., cephalosporin drugs intended for humans or companion animals);
    Using cephalosporin drugs for disease prevention.

The following drugs, or classes of drugs, approved for treating or preventing influenza A in humans, are prohibited from extra-label drug use in chickens, turkeys, and ducks:

1. Adamantanes;
2. Neuraminidase inhibitors.

A. Infectious Diseases

1. Bacterial/Mycoplasmal/Rickettsial

a. Actinobacillosis ('Wooden Tongue')

Etiology *Actinobacillus lignieresii* is an aerobic, nonmotile, nonspore forming, gram-negative coccobacilli that is widespread in soil and manure and is found as normal flora of the respiratory and upper gastrointestinal tract of ruminants. In sheep and cattle, *A. lignieresii* causes sporadic, noncontagious, and potentially chronic disease characterized by diffuse abscess and granuloma formation in tissues of the head and occasionally other body organs. This disease has not been documented in goats.

Clinical Signs Skin lesions are common, with tumorous abscesses of the tongue (cattle) and lip lesions (sheep). Soft-tissue or lymph node swelling accompanied by draining tracts are observed also in the head and neck regions, as well as other areas. The swollen tongue may protrude from the mouth causing difficulty prehending food, anorexia, and excessive salivation.

Epizootiology and Transmission The organism penetrates wounds of the skin, mouth, nose, gastrointestinal tract, testicles, and mammary gland causing chronic inflammation and abscess formation. Rough feed material and foreign bodies may play a role in causing abrasions.

Necropsy Findings Purulent discharges of white–green exudate containing small white–gray granules drain from the tracts that often extend from the area of colonization to the skin surface.

Differential Diagnosis Contagious ecthyma, caseous lymphadenitis and *Actinomyces bovis* (lumpy jaw) are the primary differentials, but rabies should also be considered. Diagnosis can be confirmed by microscopic examination of smears made from pus or by biopsy and culturing of the lesion.

Treatment IV administration of sodium iodide is the treatment of choice; oral potassium iodide also may be used. Clinical response is generally seen within 48 h of starting IV treatment. Systemic antibiotics such as ceftiofur, ampicillin, or florfenicol may be effective. Treatment can include surgical debridement and flushing with iodine.

Prevention and Control Avoid poor quality, coarse feed. Isolation or disposal of animals with disease is recommended. No vaccine is available.

b. Actinomycosis ('Lumpy Jaw')

Etiology *Actinomyces bovis* are anaerobic, nonmotile, nonspore forming, gram-positive, nonacid fast pleomorphic rods to coccobacilli associated with 'Lumpy Jaw' in cattle; rarely seen in sheep and goats.

Clinical Signs and Diagnosis *A. bovis* causes chronic, progressive, pyogranulomatous osteomyelitis of the mandible, maxillae, or other bony tissues of the head. The mass will be slow growing, firm, nonpainful and is attached to the mandible. Ulceration occurs with or without tracts draining purulent material. The alveoli of the roots of the cheek teeth are frequently involved causing loose teeth making chewing difficult. Painful eating and weight loss are evident.

Epizootiology and Transmission These organisms are normal flora of the gastrointestinal tract of ruminants and gain entrance into tissues through abrasions and penetrating wounds from wire or coarse hay or sticks. It is important to note that *Actinomyces bovis* is a zoonotic organism causing granulomas, abscesses, skin lesions, and bronchopneumonia in humans.

Necropsy Draining lesions with sulfur-like granules (as with Actinobacillosis) are frequently observed.

Differential Diagnosis *Actinobacillus lignieresii* and caseous lymphadenitis are important differentials

for draining tracts. Tumors, trauma to the affected area, such as the mandible, and dental disease or oral foreign body should also be considered.

Prevention and Control Avoid feeds with coarse or sharp ingredients.

Treatment Sodium iodide IV is the treatment of choice and is repeated several times at 7- to 10-day intervals. Concurrent antibiotic treatment may also be used, most often penicillin or oxytetracycline. Prognosis is poor in the presence of bone involvement; surgical excision is an option and may be helpful.

c. Trueperella Associated with Omphalophlebitis (See Navel Ill Below)

Omphalophlebitis, omphaloarteritis, omphalitis, and Navel Ill are terms referring to infection of the umbilicus in young animals.

Etiology *Trueperella pyogenes*, frequently combined with *E. coli*, is the most common organism causing omphalophlebitis, an acute localized inflammation and infection of the external umbilicus.

Clinical Signs Most cases occur within the first 3 months of age and animals are presented with a painful enlargement of the umbilicus. Animals may exhibit various degrees of depression and anorexia, and purulent discharges may be seen draining from the umbilicus. Involvement of the urachus is usually followed by cystitis and associated signs of dysuria, hematuria, and so on. Severe sequelae may include septicemia, peritonitis, septic arthritis ('joint ill'), meningitis, patent urachus, urachal abscesses, umbilical hernias, osteomyelitis, and endocarditis.

Diagnosis Diagnosis is by bacteriologic culture and identification of the organism.

Treatment Debridement, drainage, and antimicrobials may be useful in treatment. In addition to treatment, husbandry deficiencies resulting in poor hygine must be addressed. Animal caretakers should be trained to ensure appropriate naval dipping is occurring.

Research Complications Omphalophlebitis is a potential source for recurrent septicemia.

d. Anthrax

Etiology *Bacillus anthracis* is a zoonotic nonmotile, capsulated, spore-forming, aerobic, gram-positive bacillus that is found in alkaline soil, contaminated feeds (such as bone meal), and water. The common names for the disease are woolsorter's disease, splenic fever, charbon, and milzbrand. Cases of anthrax must be reported to animal health authorities.

Clinical Signs Anthrax is a sporadic but very serious infectious disease of cattle, sheep, and goats characterized by septicemia, hyperthermia, anorexia, depression, listlessness, and tremors. The incubation period is generally 3–7 days and ranges from peracute to chronic. The peracute form is most common in cattle and sheep and is characterized by sudden onset of staggering, dyspnea, trembling, collapse, and convulsions leading to death. Often the onset is so rapid that illness is not observed and the animal is found dead. Hematuria and bloody diarrhea often occur. The disease is usually fatal, especially in sheep and goats, after 1–3 days. Death is the result of shock, renal failure and anoxia.

Diagnosis Diagnosis based on clinical signs alone is difficult. Laboratory confirmation should be attempted: the ideal sample is a cotton swab soaked in the blood and allowed to dry. Specific tests include bacterial culture, PCR tests, and fluorescent antibody stains to demonstrate the presence of the organism. Stained blood smears may show short, single to chained bacilli. Blood may be collected from a superficial vein and submitted for culture. Western blot and ELISA blood tests for antibodies are available.

Epizootiology and Transmission Anthrax has been reported from nearly every continent; most cases in the United States occur in the central and western states. Epizootics occur in agricultural regions associated with drought, flooding, or other types of soil disturbance. Spores remain infective in the soil for many years during which time they are a potential source of infection for grazing livestock. The anthrax organisms (primarily spores) are generally ingested, sporulate, and replicate in the local tissues. Anthrax is zoonotic and may be seen in humans exposed to tissue from infected animals, contaminated animal products or directly to spores under certain conditions. Cattle and sheep tend to be affected more commonly than goats due to grazing habits.

Necropsy Necropsies should not be performed as the spores contaminate the environment. Definitive diagnoses may be made without opening the animals. Incomplete *rigor mortis*, rapid putrefaction, and dark uncoagulated blood exuding from all body orifices are common findings. Splenomegaly, cyanosis, epicardial and subcutaneous hemorrhages, and lymphadenopathy are characteristic of the disease.

Differential Diagnosis Although anthrax should always be considered when an animal that was healthy on the previous day dies acutely, other causes of acute death in ruminants should be considered, e.g., bloat, enterotoxemia, malignant edema, blackleg, and black disease.

Prevention and Control Anthrax is of particular concern as a bioterrorism agent. Control is achieved through vaccination programs and rapid detection and reporting with treatment of asymptomatic animals and burning or burial of suspect and confirmed cases. Herds in endemic areas and along waterways are routinely vaccinated with the Sterne-strain spore vaccine (virulent, nonencapsulated). The disease is a serious public health risk; a vaccine is available for personnel working with the agent.

Treatment Treatment of animals in early stages with penicillin or other long-acting antibiotics may be helpful. Vaccination should follow 7–10 days after the conclusion of antibiotic therapy. During epidemics, animals should be vaccinated with the Sterne vaccine.

Research Complications Natural and experimental anthrax infections are a risk to research personnel. The organism sporulates when exposed to air and spores may be inhaled during post mortem examinations. *B. anthracis* is considered a select agent. Readers are referred to the Center for Disease Control (CDC) National Select Agent Registry (http://www.selectagents.gov) for additional information.

e. Brucellosis

Etiology *Brucella* are nonmotile, nonspore forming, nonencapsulated, gram-negative coccobacilli. *B. abortus* (*B. melitensis biovar Abortus*) is one of several *Brucella* species that infects domestic animals but cross species infections occur rarely. *B. abortus* or *B. melitensis* may cause brucellosis in sheep, cattle and goats. *B. melitensis* (biovar 1, 2, or 3) is the primary cause of the disease in sheep but does not occur in the U.S. *B. abortus* is almost exclusively the cause of disease in cattle but has been largely eliminated in developed countries. Both *B. abortus* and *B. melitensis* are significant human pathogens. *B. ovis* causes pyogranulomatous epididymitis and orchitis, but is not zoonotic. Because brucellosis is unlikely to be encountered in research settings in developed countries, the reader is referred to the 'Major References' at the end of this chapter, and to websites such as http://www.aphis.usda.gov.

f. Campylobacteriosis (Vibriosis): *Campylobacter Fetus* Subsp. *Intestinalis; C. Jejuni*

Etiology *Campylobacter (Vibrio) fetus* subsp. *intestinalis*, a pleomorphic curved to coccoid, motile, nonspore forming, gram-negative bacterium, causes campylobacteriosis, the most important cause of ovine abortion in the United States Vibriosis is derived from the name formerly given to the genus; the term is still frequently used.

Clinical Signs and Diagnosis Ovine vibriosis is a contagious disease that causes abortion, stillbirths and weak lambs. The organism inhabits the intestines and gallbladder in subclinical carriers. Abortion generally occurs in the last trimester and abortion storms may occur as more susceptible animals, such as maiden ewes, become exposed to the infectious tissues. Some lambs may be born alive but will be weak; dams will be agalactic.

Diagnosis is achieved by microscopic identification or isolation of the organism from placenta, fetal abomasal contents, and maternal vaginal discharges using Giemsa or Ziehl–Neelsen stained smears.

Epizootiology and Transmission Campylobacteriosis occurs worldwide. *Campylobacter* spp., such as *C. jejuni*, normally inhabits ovine gastrointestinal tracts and is shed in the feces. In abortion storms, considerable contamination of the environment will occur due to shedding in placenta, fetuses, and uterine fluids. Ewes may have active *Campylobacter* organisms in uterine discharges for several months after abortion. There is no venereal transmission in the ovine.

Necropsy Aborted fetuses will be edematous with accumulation of serosanguinous fluids within the subcutis and muscle tissue fascia. The liver may contain 2- to 3-cm pale foci. Placental tissues will be thickened and edematous, and will contain serous fluids similar to the fetus. The placental cotyledons may appear gray.

Differential Diagnosis *Toxoplasma gondii*, *Chlamydophila abortus*, and *Listeria monocytogenes* should be considered in late gestation ovine abortions.

Prevention and Control A bacterin is available to prevent the disease. Carrier states have been cleared by treating with a combination of antibiotics including penicillin and oral chlortetracycline. Aborting ewes should be isolated immediately from the rest of the flock. After an outbreak, ewes will develop immunity lasting 2 or 3 years.

Treatment Infected animals should be isolated and provided with supportive therapy. Prompt decontamination of the area and disposal of the aborted tissues and discharges is important.

Research Complications Losses from abortion may be considerable. *Campylobacter* ssp. are zoonotic agents and *C. fetus* ssp. *intestinalis* may be the cause of 'shepherd's scours.'

g. Campylobacteriosis (Bovine *Vibriosis*): *Campylobacter Fetus* Subsp. *Venerealis*

Etiology *Campylobacter fetus* subsp. *venerealis* is the main cause of bovine Campylobacteriosis abortions. It does not cause disease in other ruminant species.

Clinical Signs and Diagnosis Preliminary signs of a problem in the herd will be a high percentage of cows returning to estrus after breeding and temporary infertility. This will be particularly apparent in virgin heifers that may return to estrus by 40 days after breeding. Spontaneous abortions may occur, typically during the 5th to 8th months of gestation. The aborted fetus may be fresh or severely autolyzed. Severe endometritis may lead to salpingitis and permanent infertility.

Demonstration or isolation of the organism, a curved rod with corkscrew motility, is the basis for diagnosis. Campylobacter can be identified by darkfield examination of abomasal contents or from culture of the placenta or abomasal contents. A fluorescent antibody test on genital discharge from the bull or cow can also

be diagnostic; a PCR test is available for detection of *Campylobacter* in semen.

Epizootiology and Transmission The bacterium is an obligate, ubiquitous organism of the genital tract. Transmission is from infected bulls to heifers. Bulls are carriers of the disease but show no clinical signs. Older cows develop effective immunity.

Necropsy Findings Necrotizing placentitis with hemorrhagic cotyledons, dehydration, and fibrinous serositis will be found grossly. In addition, bronchopneumonia and hepatitis will be seen histologically.

Differential Diagnosis The primary differential for campylobacteriosis in cattle is trichomoniasis. Other differentials include brucellosis, mycoplasmosis, infectious bovine rhinotracheitis–pustular vulvovaginitis (IBR–IPV), bovine viral diarrhea (BVD), and leptospirosis.

Prevention and Control Killed bacterin vaccines are available; annual boosters should be given after the initial immunization and as part of the regular prebreeding regimen. AI is particularly useful at controlling the disease.

Treatment Cows will usually recover from the infection. Treatment with antibiotics, such as penicillin, administered as an intrauterine infusion improves the chances of returning to breeding condition.

h. Caprine Staphylococcal Dermatitis

Etiology The most common caprine bacterial skin infection is caused by *Staphylococcus intermedius* or *S. aureus* and is known as staphylococcal dermatitis (Smith and Sherman, 2009). The *Staphylococcus* organisms are cocci and are categorized as primary pathogens or ubiquitous skin commensals of humans and animals.

Clinical Signs and Diagnosis Small pustular lesions, caused by bacterial infection and inflammation of the hair follicle, occur around the teats and perineum. Occasionally, the infection may involve the flanks, underbelly, axilla, inner thigh, and neck. Diagnosis is based on lesions and positive culture.

Differential Diagnosis Contagious ecthyma is a differential diagnosis along with fungal skin infections and nutritional causes of skin disease.

Treatment Severe infections should be treated with antibiotics based on culture and sensitivity. Lesions may benefit from periodic cleaning with an iodophor shampoo and spraying with an antibiotic and an astringent (Smith and Sherman, 2009).

i. Clostridial Diseases

i. C. PERFRINGENS, *TYPE C (ENTEROTOXEMIA AND STRUCK)*

Etiology *C. perfringens* is an anaerobic, gram-positive, non-motile, spore-forming bacterium that lives in the soil, contaminated feed and gastrointestinal tracts of ruminants. The bacterium is categorized by toxin production. Toxins include alpha (hemolytic), beta (necrotizing), delta (cytotoxic and hemolytic), epsilon, and iota. Types of *C. perfringens* are A, B, C, D, and E. Infection is a common and economically significant disease of sheep, goats, and cattle.

Clinical Signs and Diagnosis The lethal beta toxin associated with overgrowth of this bacterium results in a hemorrhagic enterocolitis within the first 72 h of a well-fed young ruminant's life. Animals may simply be found dead with no clinical presentation. Affected animals are acutely anemic, dehydrated, anorexic, depressed, and may display tremors or convulsions as well as abdominal pain. Calves experience an acute diarrhea, dysentery, abdominal pain, convulsions, and opisthotonos with death occurring in a few hours. Less severe cases can survive for a few days and recovery is possible. Feces may range from loose gray–brown to dark red and malodorous. Morbidity and mortality may be nearly 100%.

A similar noncontagious but acutely fatal form of enterotoxemia in adult sheep, called 'Struck,' occurs in yearlings and adults. Struck is rare in the United States. The disease is also caused by the beta toxin of *C. perfringens* type C and is often associated with rapid dietary changes or shearing stresses in sheep. Although affected animals are usually found dead, clinical signs include uneasiness, depression, and convulsions. Mortality is usually less than 15%.

Diagnosis is usually based on necropsy findings. Identification of the beta toxin in intestinal contents may be difficult due to instability of the toxin, but filtrates made for detection of toxin and future identification by neutralization with specific antisera is possible.

Epizootiology and Transmission Clostridial organisms are ubiquitous in the environment as well as in the gastrointestinal tract and contaminated feeds. Transmission is by ingestion of contaminated material.

Necropsy Findings Necropsy findings include a milk-filled abomasum as well as hemorrhage in the distal small and large intestines. The affected portion of the intestine may be deep blue to purple in color and resemble a mesenteric torsion. Petechial hemorrhages of the serosal surfaces of many organs, especially the thymus, heart, and gastrointestinal tract will be visible. Hydropericardium, hydroperitoneum, and hemorrhagic mesenteric lymph nodes will also be present. Pulmonary and brain edema may also be seen (Blackwell and Butler, 1992).

Differential Diagnoses Other Clostridial diseases such as blackleg and black disease as well as coccidiosis, salmonellosis, anthrax, and acute poisoning.

Prevention and Control A commercial toxoid is available and should be administered to the pregnant animals during the last third of preganancy. Initial vaccination of young animals should consist of two vaccinations, 1 month apart, and then annually.

Treatment Treatment is difficult and usually unsuccessful due to the severity of the disease. Antitoxin may be useful in milder cases, and antiserum may be administered immediately after birth in the face of an outbreak.

ii. C. PERFRINGENS, *TYPE D (PULPY KIDNEY DISEASE)*

Etiology *C. perfringens* type D releases epsilon toxin that is proteolytically activated by trypsin. This disease caused by *C. perfringens* tends to be associated with sheep and is of less importance in goats and cattle.

Clinical Signs The peracute condition in younger animals is characterized by sudden deaths, which are occasionally preceded by neurological signs such as incoordination, opisthotonus, and convulsions. Because the disease progresses so rapidly to death (within 1–2 h) clinical signs are rarely observed. The largest, fastest-growing animals generally are predisposed to this condition.

Necropsy Findings These are similar to those seen with *C. perfringens* type C. Additionally, extremely necrotic, soft kidneys ('pulpy kidneys') are usually observed immediately following death. Focal encephalomalacia, and petechial hemorrhages on serosal surfaces of the brain, diaphragm, gastrointestinal tract and heart are common findings. See Uzal and Songer (2008) for further information.

Differential Diagnosis Tetanus, enterotoxigenic *E. coli*, botulism, polioencephalomalacia, grain overload, and listeriosis are differentials.

Prevention and Control Vaccination prevents the disease. Maternal antibodies last approximately 5 weeks postpartum; thus, young animals should be vaccinated at about this time. Feeding regimens to young or fast-growing animals and feeding of concentrates to adults should be evaluated carefully.

Treatment Treatment consists of support (fluids, warmth), antitoxin administration, oral antibiotics, and diet adjustment.

iii. C. TETANI *(TETANUS, LOCKJAW)*

Etiology *Clostridium tetani* is a strictly anaerobic, motile, spore forming, gram-positive rod that persists in soils, manure, and within the gastrointestinal tract. Tetanus toxemia is caused by a specific neurotoxin produced by *Clostridium tetani* in necrotic tissue. It is introduced into the tissue through wounds, specifically deep punctures which provide the necessary anaerobic environment. The uterus is the most common site of infection in post parturient dairy cattle with retained placentas. Banding castrations are another common etiology of the condition.

Clinical Signs Infection by *C. tetani* is characterized by a sporadic, acute, and fatal neuropathy. After an incubation period of 4 days to 3 weeks, the animal exhibits bloat, muscular spasticity, prolapse of the third eyelid, rigidity and extension of the limbs leading to a stiff gait, an inability to chew, and hyperthermia. Retracted lips, drooling, hypersensitivity to external stimuli, and a 'saw-horse' stance are frequent signs. The animal may convulse. Death occurs within 3–10 days and mortality is nearly 100%, primarily from respiratory failure. Diagnosis is based on clinical signs.

Epizootiology and Transmission *C. tetani* is a soil contaminant and is often found as part of the gut microflora of herbivores. The organisms sporulate and persist in the environment. All species of livestock are susceptible, but sheep and goats are more susceptible than cattle, with horses being the most susceptible. Individual cases may occur or herd outbreaks may follow castration, tail docking, ear tagging, or dehorning.

Differential Diagnoses Differentials include bloat, rabies, hypomagnesemic tetany, polioencephalomalacia, white muscle disease, enterotoxemia in lambs, and lead poisoning.

Necropsy Findings Findings are nonspecific except for the inflammatory reaction associated with the wound.

Treatment Treatment consists of cleaning and aggressively debriding the infected wound, administration of tetanus antitoxin, vaccination with tetanus toxoid, administration of antibiotics both parenterally and flushed into the cleaned wound, a sedative or tranquilizer and a muscle relaxant, and keeping the animal in a dark, quiet environment. Supportive fluids and glucose must be administered until the animal is capable of feeding.

Prevention and Control The disease can be controlled and prevented by following good sanitation measures, aseptic surgical procedures, and vaccination programs. Tetanus toxoid vaccine is available and very effective for stimulating long-term immunity. Animals should be vaccinated two to three times during the first year of life. Does and ewes should receive booster vaccinations within 2 months of parturition to ensure colostral antibodies. For sheep, goats, and cattle, the tetanus toxoid vaccine is available in combination with other clostridial diseases. Tetanus antitoxin can be administered as a preventative or in the face of disease as an adjunct to therapy.

Research Complications Unprotected, younger ruminants may be affected following routine flock or herd management procedures.

iv. C. NOVYI *(BIGHEAD; BLACK DISEASE; BACILLARY HEMOGLOBINURIA [RED WATER])*; C. CHAUVOEI *(BLACKLEG)*

Etiology *Clostridium novyi*, an anaerobic, motile, spore-forming, gram-positive bacteria, is the agent of bighead and black disease. *C. novyi* Type D (*C. hemolyticum*) is the cause of bacillary hemoglobinuria. *C. chauvoei* is the causative agent of blackleg.

Clinical Signs Bighead is a disease of rams characterized by a nongaseous, nonhemorrhagic edema of the head and neck. The edema may migrate to ventral regions such as the throat. Additional clinical signs include swelling of the eyelids, and nostrils. Most animals will die within 48–72 h. Black disease or infectious necrotic hepatitis is a peracute, fatal disease associated with *C. novyi*. It is more common in cattle and sheep, but may be seen in goats. The clinical course is 1–2 days in cattle, and slightly shorter in sheep. Otherwise healthy-appearing 2- to 4-year-old animals are often affected. Clinical signs are rarely seen because of the peracute nature of the disease. Occasionally, hyperthermia, tachypnea, inability to keep up with other animals, and recumbency are observed prior to death. Bacillary hemoglobinuria is an acute disease seen primarily in cattle, characterized by fever and anorexia in addition to the hemoglobinemia and hemoglobinuria indicated by the name. Animals that survive a few days will develop icterus. Mortality may be high.

Blackleg, a disease similar to bighead, causes necrosis and emphysema of muscle masses (clostridial myositis), serohemorrhagic fluid accumulation around the infected area, and edema. Blackleg is more common in cattle than sheep. The clinical course is short, 24–48 h, and animals die regardless of treatment. Blackleg in cattle can be associated with subcutaneous edema or crepitation; these lesions do not usually occur in sheep. Most lesions are associated with muscles of the face, neck perineum, thigh, and back.

Epizootiology and Transmission Bighead is caused by the toxins of *C. novyi* which enters through wounds often associated with horn injuries during fighting. *C. novyi* Type D is endemic in western USA *C. chauvoei* spores remain viable in the soil for years and are the potential source of infection. Outbreaks are often seen after excavation or flooding and are more common in summer and fall. It is suspected the organism is ingested, gains access to the bloodstream via the gastrointestinal tract and enters the muscles. Black disease and bacillary hemoglobinuria are associated with concurrent liver disease often associated with *Fasciola* infections (liver flukes); it is sometimes seen as sequelae to liver biopsies. Ingested spores are believed to develop in hepatic tissue damaged and anoxic from the fluke migrations.

Necropsy Diagnosis of black disease is usually based on *post mortem* lesions. Subcutaneous vessels will be engorged with blood resulting in dried skin having a dark appearance. Carcasses putrefy quickly. In addition, hepatomegaly and endocardial hemorrhages are common, and hepatic damage from flukes may be so severe that diagnosis is difficult.

Differential Diagnosis Differentials include other clostridial diseases; hemolytic diseases such as babesiosis, leptospirosis, and hemobartonellosis; and photosensitization.

Treatment For *C. chauvoei* and bighead, early aggressive treatment including aggressive wound debridement, oxygenation, and penicillin or tetracycline may be helpful. Treatment for black disease is not rewarding. For *C. novyi (C. haemolyticum)* early treatment with penicillin or tetracycline in high doses along with a blood transfusion and fluids may be helpful.

Prevention and Control Vaccinating animals with multivalent clostridial vaccines will prevent these diseases and may be useful in an outbreak. Control of fascioliasis is very important in prevention and control of black disease.

v. C. SEPTICUM *(MALIGNANT EDEMA)*

Etiology *Clostridium septicum* is the species usually associated with malignant edema, but mixed infections involving other clostridial species such as *C. chauvoei*, *C. novyi*, *C. sordelli*, and *C. perfringens* may occur.

Clinical Signs Malignant edema or gas gangrene is an acute and often fatal bacterial disease caused by clostridium spp. The affected area will be warm and will contain gaseous accumulations that can be palpated as crepitation of the subcutaneous tissue around the infected area. The skin over the infected area generally has a blue color characteristic of gangrene. Regional lymphadenopathy and fever may occur. The animal becomes anorexic, severely depressed and possibly hyperthermic. Pitting edema and crepitation may be noted around the wound; death occurs within 12 h to 2 days.

Epizootiology and Transmission The organisms are ubiquitous in the environment worldwide, are found in the intestinal contents of animals, and may survive in the soil for years. The disease is especially prevalent in animals that have had recent wounds containing devitalized tissue such as those that have undergone castration, docking, ear notching, shearing, or dystocia.

Necropsy Findings The tissue necrosis and hemorrhagic serous fluid accumulations resemble those of other clostridial diseases. Spreading, crepitant lesions around wounds are suggestive of malignant edema. Gas and serosanguineous fluids with foul odors infiltrate the tissue planes.

Treatment Infected animals can be treated with large doses of penicillin, anti-inflammatories and fenestration of the wound is recommended. Affected tissues usually slough.

Prevention and Control Proper preparation of surgical sites, sanitation of instruments and the housing environment and attention to post-operative wounds will help prevent this disease. Multivalent clostridial vaccines are available.

j. Colibacillosis

Etiology *Escherichia coli* is a motile, aerobic, gram-negative, nonspore-forming coccobacillus commonly

found in the environment and gastrointestinal tracts of ruminants. *E. coli* organisms have three areas of surface antigenic complexes ('O' – somatic, 'K' – envelope or pili, and 'H' – flagellar) that are used to 'group' or classify serotypes. Colibacillosis is the common term for infections in younger animals caused by this bacterium.

Clinical Signs Presentation of *E. coli* infections vary with the animal's age and the type of *E. coli* involved. Exposure is primarily fecal–oral but can also occur through the umbilicus. Entertoxigenic *E. coli* infection causes gastroenteritis and/or septicemia in neonates. Colibacillosis generally develops within the first 72 h of life when newborn animals are exposed to the organism. The enteric infection causes a semifluid, yellow to gray diarrhea. Occasionally blood streaking of the feces may be observed. Listlessness along with a loss of suckling interest is followed by abdominal pain, evidenced by arching of the back and extension of the tail. Hyperthermia is rare and temperature may be subnormal. Severe acidosis, depression, recumbancy, and lack of response to external stimuli ensue. Mortality may be as high as 75%. This form of the disease is very acute with the clinical course lasting only 3–8 h. The septicemic form generally occurs between 2 and 6 weeks of age. Animals display an elevated body temperature and show signs suggestive of nervous system involvement such as incoordination, head pressing, circling and the appearance of blindness. Opisthotonos, depression and death follow due to endotoxemic shock. Occasionally, swollen, painful joints may be observed with septicemic colibacillosis. Blood cultures may be helpful in identifying the septicemic form.

In ruminants, *E. coli* also may cause cystitis and pyelonephritis. Cystitis is characterized by dysuria and pollakiuria, although gross hematuria and pyuria may be present. In cases of pyelonephritis, a cow will be acutely depressed, have a fever, ruminal stasis, and be anorectic.

Epizootiology and Transmission *E. coli* is one of the most common gram-negative pathogens isolated from ruminant neonates affecting calves and lambs. Overcrowding, poor sanitation, and failure of passive immune transfer contribute significantly to the development of this disease in young animals. The organism will be endemic in a contaminated environment and present on dams' udders. The bacteria rapidly proliferate in the neonates' small intestines. The bacteria and associated toxins cause a secretory diarrhea resulting in the loss of water and electrolytes. If the bacteria infiltrate the intestinal barrier and enter the blood, septicemia results. Immunoglobulin-deficient calves are far more susceptible to both enteritis and septicemia.

Diagnosis Diagnosis of the enteric form can be made by observation of clinical signs including diarrhea, staining of the tail and wool and demonstration of a deficiency of circulating IgG. ELISA and latex agglutination tests are available diagnostic tools.

Necropsy Findings Swollen, yellow to gray, fluid-filled small and large intestines, swollen and hemorrhagic mesenteric lymph nodes, and generalized tissue dehydration are common. Septicemic animals may have serofibrinous fluid in the peritoneal, thoracic and pericardial cavities, enlarged joints containing fibrinopurulent exudates, and congested and inflamed meninges.

Differential Diagnosis These include the enterotoxemias caused by *C. perfringens* A, B, or C; *Campylobacter jejuni*; *Coccidia* spp., rotavirus, coronavirus, *Salmonella*, *Streptococcus* spp., *Pasteurella* spp., and *Cryptosporidia*.

Prevention and Control The best preventative measures include scrupulous attention to colostrum quality and delivery, prevention of overcrowding and frequent sanitization of maternity areas.

Treatment Antibiotics with known efficacy against gram-negative organisms such as trimethoprim/sulfadiazine, enrofloxacin, cephalothin, and ceftiofur may be helpful. Oral antibiotics are not recommended. Aggressive use of Ringers solution supplemented with dextrose and electrolytes is critical, including bicarbonate for metabolic acidosis, and nonsteroidal anti-inflammatories help with pain relief. High mortalities should be expected even with quick and aggressive intervention. Vaccines may be given to the dam prior to calving to boost colostral immunity.

k. *Corynebacterium pseudotuberculosis* (Caseous Lymphadenitis)

Etiology *Corynebacterium pseudotuberculosis* (previously *C. ovis*) is a nonmotile, nonspore forming, aerobic, short and curved, gram-positive coccobacilli. Caseous lymphadenitis (CLA) is such a common, chronic contagious disease of sheep and goats that any presentation of abscessing and draining lymph nodes should be presumed to be this disease until proven otherwise. The disease has been reported occasionally in cattle.

Clinical Signs and Diagnosis Abscessation of both superficial and deep lymph nodes is typical. Radiographs may be helpful in identifying affected central nodes. Peripheral lymph nodes may erode and drain caseous, 'cheesy,' yellow–green–tan secretions. The incubation period may be weeks to months. Over time, an infected animal may become exercise-intolerant, anorectic, and debilitated. Fever, increased respiratory rates, and pneumonia may also be common signs. Morbidity up to 15% is common, and morbid animals will often eventually succumb to the disease. See Dorella *et al.* (2006) for additional discussion.

Diagnosis is based on clinical lesions, and culturing or gram-staining of lymph node aspirates. ELISA serological testing is also available.

Epizootiology and Transmission The organism can survive for 6 months or more in the environment and enters via skin wounds such as shearing, castration, or docking. Ingestion and aerosolization (leading to pulmonary abscesses) have been reported as alternative routes of entry.

Necropsy Findings Disseminated superficial abscesses as well as lesions of the mediastinal and mesenteric lymph nodes will be identified. Cut surfaces of the affected lymph nodes may appear lamellated. Lungs, liver, spleen, and kidneys may also be affected. Cranioventral lung consolidation with hemorrhage, fibrin, and edema are seen histologically.

Differential Diagnosis Differentials include pathogens causing lymphadenopathy and abscessation as well as injection site reactions from clostridial vaccines.

Treatment Antibiotic therapy is not usually helpful. Abscesses can be surgically lanced and flushed with iodine-containing and/or hydrogen peroxide solutions, or removed entirely from valuable animals. Because of the contagious nature of the disease, animals with draining and lanced lesions should be isolated from CLA-negative animals at least until healed. Commercial vaccines are available (Piontkowski and Shivvers, 1998).

Prevention and Control Minimizing contamination of the environment, proper sanitation methods for facilities and instruments, segregation of affected animals, and precautions to prevent injuries are all important.

Research Complications This pathogen is a risk for animals undergoing routine management procedures, or invasive research procedures, due to the persistence in the environment, a long clinical incubation period, and poor response to antibiotics.

l. *Corynebacterium renale*, *C. cystitidis*, and *C. pilosum* (Pyelonephritis, Posthitis, and Ulcerative Vulvovaginitis)

Etiology *Corynebacterium renale*, *C. cystitidis*, and *C. pilosum* are sometimes referred to as the '*C. renale* group.' These are piliated and non-motile gram-positive rods and are distinguished biochemically. *C. renale* causes pyelonephritis in cattle, and *C. pilosum* and *C. cystitis* cause posthitis, also known as pizzle rot or sheath rot, in sheep and goats. The bacteria are ubiquitous in the environment and inhabit the vagina and prepuce. High-protein diets, resulting in higher urea excretion, more basic urine, and irritation of the preputial and vaginal mucous membranes are contributing factors.

Clinical Signs and Diagnosis Acute pyelonephritis is characterized by fever, anorexia, polyuria, hematuria, pyuria, and arched-back posture. First signs may be blood-tinged urine in a seemingly normal cow. Untreated infections usually become chronic with discomfort, frequent urination, weight loss, anorexia, hematuria or pyuria and loss of production in dairy animals. Chronic cases are characterized by diarrhea, polyuria, polydipsia, stranguria, and anemia. Relapses are common, and some infections are severe and fatal. Diagnosis of pyelonephritis is based on clinical signs and urinalysis (proteinuria and hematuria) and rectal or vaginal palpation (assessing ureteral enlargement).

Posthitis and vulvovaginitis are characterized by ulcers, crusting, swelling, and pain. The area may have a distinct malodor. Necrosis and scarring may be sequelae of more severe infections. Fly strike may also be a complication. Diagnosis is based on clinical signs.

Epizootiology and Transmission Although ascending urinary tract infections with cystitis, ureteritis, and pyelonephritis are widespread problems, the incidence is relatively low. The vaginitis and posthitis contribute to venereal transmission. Indirect transmission is possible because organisms are present on wool or scabs shed from affected animals. Posthitis occurs in intact and castrated sheep and goats.

Necropsy Findings Pyelonephritis, multifocal kidney abscessation, dilated and thickened ureters, cystitis, and purulent exudate in many sections of the urinary tract are common findings at gross necropsy.

Differential Diagnosis Urolithiasis is a primary consideration for these diseases. Contagious ecthyma should be considered although the lesions of contagious ecthyma are more likely to develop around the mouth.

Prevention Feeding practices must be reconsidered. Clipping long wool and hair also is helpful. Affected animals should be isolated to control build-up of the organisms.

Treatment Long term (3 weeks) penicillin administration is effective for pyelonephritis as is trimethoprim-sulfadioxine for 3 weeks. Reduction of dietary protein, clipping and cleaning skin lesions, treating for or preventing fly strike, and topical antibacterial treatments are effective for posthitis/vulvovaginitis; systemic therapy may be necessary for severe cases.

m. Dermatophilosis (Cutaneous Streptothricosis, Lumpy Wool, Strawberry Footrot)

Etiology *Dermatophilus congolensis* is a gram-positive, nonacid-fast, facultative anaerobic actinomycete. Dermatophilosis is a chronic bacterial skin disease characterized by crustiness and exudates accumulating at the base of the hair or wool fibers. Various strains can be present within a group of animals experiencing an outbreak. The natural habitat of the organism is unknown as it has not been successfully isolated from soil.

Clinical Signs Animals will be painful but not pruritic. Two forms exist in sheep, mycotic dermatitis (also known as lumpy wool) and strawberry footrot. Mycotic

dermatitis is characterized by crusts and wool matting with exudates over the back and sides of adult animals and about the face of lambs. Strawberry footrot is rare in the United States but is characterized by crusts and inflammation between the carpi and/or tarsi and the coronary bands. Animals will be lame. In goats and cattle, similar clinical signs of crusty, suppurative dermatitis are seen; the disease is often referred to as cutaneous streptothricosis in these species. In cattle, most lesions are raised, matted tufts of hair and are distributed over the head, dorsal surfaces of the neck and body. Lesions in younger goats are seen along the tips of the ears and under the tail. Most affected animals will recover within 3–4 weeks and lesions have little effect on overall health. Animals that develop severe generalized infections often lose condition. Movement and eating become difficult if the feet, lips and muzzle are involved. Cattle with lesions over 50% of their bodies are likely to become seriously ill. Rare human infections have occurred from handling diseased animals.

Diagnosis Diagnosis is based on clinical signs as well as the typical microscopic appearance on stained skin scrapings and crusts, cultures and serology. The organism can be isolated via culture and/or skin biopsy.

Epizootiology and Transmission The disease occurs worldwide and the *Dermatophilus* organism is believed to be a saprophyte. Transmission occurs by direct contact with infected animals, although contaminated environments and biting insects are also suspected indirect methods of transmission. Development of disease may be influenced by factors such as prolonged wetness, high humidity, high temperatures, and ectoparasites such as ticks and lice which serve to reduce the natural barriers of the skin.

Necropsy Findings Death is unusual so necropsy is not often performed.

Prevention and Control Potash alum and aluminum sulfate have been used as wool dusts in sheep to prevent dermatophilosis. Minimizing moist conditions is helpful in controlling and preventing the disease. In addition, controlling external parasites or other factors that cause skin lesions is important. Lesions will resolve during dry periods.

Treatment Animals can be treated with antibiotics such as penicillin and oxytetracycline as the organism is susceptible to a wide range of antibiotics. Antimicrobial therapy is augmented by topical applications of lime sulfur as well as control of ectoparasites and biting flies. Treating the animals with povidone iodine shampoos or chlorhexidine solutions also is useful in clearing the disease.

Research Complications *D. congolensis* is a zoonotic organism. Research personnel must be trained in zoonosis and should fully understand the risks of working with infected animals.

n. *Dichelobacter* (*Bacteroides*) *nodosus* and *Fusobacterium necrophorum* (Virulent Foot Rot; Contagious Foot Rot of Sheep and Goats; Footscald)

Etiology Two bacteria, *Dichelobacter* (*Bacteroides*) *nodosus* and *Fusobacterium necrophorum*, work synergistically in causing contagious foot rot in sheep and goats. Both are nonmotile, nonspore forming, anaerobic, gram-negative bacilli. Foot rot is a contagious, acute or chronic dermatitis involving the hoof and underlying tissues (Bulgin, 1986). It is the leading cause of lameness in sheep. Footscald, an interdigital dermatitis is caused primarily by *D. nodosus* alone.

Clinical Signs Varying degrees of lameness are observed in all ages of animals within 2–3 weeks of exposure to the organisms. Severely infected animals will show generalized signs of weight loss, decreased productivity, and anorexia associated with an inability to move. The interdigital skin and hooves will be moist with a very distinct necrotic odor. Diagnosis is based on clinical signs. Smears and cultures confirm the definitive agents. Clinical signs of the milder disease, footscald, include mild lameness, redness and swelling, and little to no odor.

Epizootiology and Transmission *F. necrophorum* is ubiquitous in soil and manure, in the gastrointestinal tract, and on the skin and hooves of domestic animals. In contrast, *Dichelobacter* is an obligate pathogen of the ovine foot; the organism contaminates the soil and manure but rarely remains in the environment for over about 2 weeks. Some animals may be chronic carriers. Overcrowded, warm and moist environments are key elements in transmission.

Differential Diagnoses Foot abscesses, selenium/vitamin E deficiencies, strawberry footrot, bluetongue virus infection (manifested with myopathy and coronitis), and trauma are among the many differentials that must be considered.

Treatment Affected animals are best treated by manually trimming the necrotic debris from the hooves, followed by application of local antibiotics and foot wraps. Systemic antibiotics such as penicillin, oxytetracycline, and erythromycin may be used. Footbaths containing 10% zinc or copper sulfate or 10% formalin (not legal in all states) can be used for treatment as well as prevention of the disease. Affected animals should be separated from the flock See Kimberling and Ellis (1990) for more information.Vaccination has been shown to be effective as part of the treatment regimen.

Prevention and Control These programs involve scrutiny of herd and flock management; quarantine of incoming animals; vaccination; segregation of affected animals; careful and regular hoof trimming; avoiding muddy pens and holding areas; and culling individuals with chronic and nonresponsive infections. *D. nodosus*

bacterins are commercially available, but cross protection between serotypes varies. Footbaths are also considered effective preventative measures. Due to the potential for toxicity, copper sulfate footbaths should be employed with great caution in sheep.

Research Complications Treating and controlling footrot is very costly in terms of time, treatment and follow-up, and extra housing space requirements.

o. *Fusobacterium necrophorum* and *Prevotella melaninogenic* (Formerly *Bacteroides melaninogenicus*) (Footrot of Cattle, Interdigital Necrobacillosis, Interdigital Phlegmon of Cattle, Foot Abscesses of Sheep)

Etiology Interdigital necrobacillosis of cattle is caused by *F. necrophorum* and several other organisms. Incidence in cattle has decreased as dairy cows spend less time on pasture, however foot rot still causes up to 15% of claw diseases. *F. necrophorum* is also associated with foot abscesses or infection of the deeper structures of the foot in sheep and goats. One or both claws of the affected hoof may be involved. Animals will be 'three-legged lame' and the affected hoof will be hot. Pockets of purulent material may be in the heel or toe.

Clinical Signs and Diagnosis Clinical signs include mild-to-moderate lameness of sudden onset. Hindlimbs are more commonly affected. The interdigital space will be swollen, as will be the coronet and bulb areas. The claws will be markedly separated and inflammation may extend to the pastern and fetlock. Characteristic malodors will be noted, but there will be little purulent discharge. In more severe cases, animals will have elevated body temperatures and loss of appetite. Lesions progress to fissures with necrosis until sloughing and healing occurs. The diagnosis is by the odor and appearance. If the condition is not treated and allowed to progress, weight loss and decrease in milk production will occur. Diagnosis is based on clinical signs, assessment of the environmental and housing conditions of the animal and anaerobic culture confirms the organisms involved.

Epizootiology and Transmission Cases may be sporadic or epizootics may occur. Dairy cattle breeds are more commonly affected.

Necropsy Findings These include dermatitis and necrosis of the skin and subcutaneous tissues. Although necropsy would rarely be performed, secondary osteomyelitis may be noted in severe cases.

Differential Diagnoses The most common differentials for sudden lameness include hairy heel warts, laminitis, and subsolar abscesses. Bluetongue virus should also be considered.

Prevention and Control As with footrot in smaller ruminants, management of the area and herd are important. Paddocks and pens should be kept dry and well drained and free of material that will damage feet. Footbaths have been shown to control incidence. Affected animals should be segregated during treatment. Chronically affected or severely lame animals should be culled. New cattle should be quarantined and evaluated.

Treatment Successful treatment includes cleaning the feet; trimming necrotic tissue; and use of parenteral antimicrobials such as ceftiofur, oxytetracycline, or procaine penicillin. Twice-a-day footbaths (such as 10% zinc sulfate, 2.5 % formalin when allowed, or 5% copper sulfate) can be effective. In severe cases, more aggressive therapy such as bandaging the feet may be needed. Animals can recover without treatment but may be lame for several weeks.

Research Complications These are comparable to those noted for footrot in smaller ruminants.

p. Heel Warts (Bovine Digital Dermatitis, Papillomatous Digital Dermatitis [PDD], Hairy Foot Warts)

Etiology Digital dermatitis is highly contagious and can cause morbidity of up to 90% in a herd. The causative agent of digital dermatitis is uncertain and may be caused by more than one bacterium. Bacteria such as *Fusobacteria* spp., *Prevotella* spp. (*Bacteroides* spp, *Treponema*), and *Dichelobacter nodosus* have been isolated from bovine heel lesions. Several species of *Treponema* have also been confirmed in the lesions of cows with papillomatous digital dermatitis (PDD) in the United States and Europe.

Clinical Signs All lesions occur on the haired digital skin. One or more feet may be affected. Most lesions occur on the plantar surface of the hind foot (near the heel bulbs and/or extending from the interdigital space), but the palmer and dorsal aspect of the interdigital spaces may also be involved. Moist plaques begin as red, granular areas; plaques enlarge, turn gray or black, and 'hairs' protrude from the roughened surface. Lesioned areas are very painful. Heel warts differentiate from foot rot as swelling and fever are absent.

Epizootiology and Transmission Poorly drained loafing areas, damp and dirty bedding areas, and overcrowding have been implicated as contributing factors. Interdigital lesions occur commonly in young stock and dairy facilities throughout the world. Introduction of new cattle into a herd that has not previously been affected can cause a large outbreak. The disease is seen only in cattle.

Differential Diagnoses Differentials for lameness will include foot rot, sole abscesses, laminitis, and trauma.

Prevention and Control Biosecurity is a key component for control. Purchasing replacement heifers should be avoided in uninfected herds. Equipment used for hoof trimming should be sterilized. Trucks and

trailers should be sanitized between groups. Routine use of footbaths that contain copper sulfate, zinc sulfate, formalin, or antibiotics such as tetracycline or lincomycin have been useful in reducing incidence. The footbaths must be well maintained, minimizing contamination by feces and other materials. Tandem arrangements, such as use of cleaning footbaths followed by medicated footbaths or sprays are useful.

Treatment Lesions should be debrided or removed followed by topical antibiotic and antiseptic regimens.

Research Complications PPD is one of the major causes of lameness among heifers and dairy cattle and is a costly problem to treat.

q. *Histophilus somni* (Formerly *Haemophilus somnus*) (Thromboembolic Meningoencephalitis [Teme])

Etiology *Histophilus somni* is a pleomorphic, n on (Kirk and Glenn, 1996)bencapsulated, nonsporeforming gram-negative coccobacillus. Diseases caused by this organism include thromboembolic meningoencephalitis, septicemia, arthritis, and reproductive failures due to genital tract infections in males and females. *H. somni* is a commensal of the bovine mucous membranes; pathogenic and non-pathogenic strains have been found. The nasal and urogenital secretions are believed to be the source of the organism and a major contributor to the bovine respiratory disease complex (BRDC). *Histophilus* spp. also have been associated with respiratory disease in sheep and goats.

Clinical Signs Sudden death is often the first sign noted of *H. somni* pneumonia in a group of animals. If animals are found prior to death, marked dyspnea is present. Depression is often the first notable sign of the neurologic presentation. Other clinical signs include ataxia, falling, and conscious proprioceptive deficits. Clinical signs such as head tilt from otitis interna-media, opisthotonus and convulsions may be seen when the brainstem is affected. High fever, extreme morbidity and death within 36 h may occur. Respiratory infections with *H. somni* contribute to BRDC in conjunction with one of the respiratory viruses. In acute neurologic as well as chronic pneumonic infections, polyarthritis may develop. *H. somni* may cause abortion, vulvo-vaginitis, endometritis, placentitis and infertility.

Diagnosis is achieved by examination of tissues collected at necropsy. Isolation of the organism from CSF, brain, blood, urine, joint fluid or other internal organs is confirmatory. Paired serum samples are recommended.

Epizootiology and Transmission Because the organism is considered part of the normal flora of cattle and can be isolated from numerous tissues, the distinction between the normal flora and the status of chronic carrier is not clear. After inhalation, the organism colonizes the respiratory tract and gains access to the bloodstream. Colonization of the male and female reproductive tracts may lead to venereal spread. Stresses of travel and co-infection with other respiratory pathogens may be involved. Transmission is by respiratory and genital tract secretions. The organism does not persist in the environment.

Necropsy Findings Pathognomonic central nervous system lesions include multifocal red–brown foci of necrosis and inflammation on and within the brain and the meninges. Many thrombi with bacterial colonies will be seen in these affected areas. Ocular lesions may also be seen including conjunctivitis, retinal hemorrhages and edema. The respiratory tract lesions include bronchopneumonia and fibrinous pleuritis. A focal myocardial lesion (in the papillary muscle of the left ventricle) along with fibrinous pericarditis, bronchopneumonia, polyarthritis, and fibrinous laryngitis may also be seen. Aborted fetuses will not show lesions, but necrotizing placentitis will be evident histologically. Pure cultures of *H. somni* may be possible from these tissues.

Differential Diagnoses Differentials in all ruminants include other pathogens associated with neurological disease and respiratory disease such as *M. hemolytica* and *P. multocida*. In smaller ruminants, *C. pseudotuberculosis* should be considered.

Prevention and Control The organism is susceptible in vitro to many antimicrobials. However, the use of antibiotics metaphylactically has not shown great success. Late-stage polyarthritis is resistant to antibiotic therapy due to failure to reach the site of infection. Planning vaccination programs carefully will decrease chances of outbreaks; for example; vaccinations for respiratory pathogens should be avoided during times of acute stress. Killed whole-cell bacterins are commercially available that produce a humoral response. Calves should be immunized prior to entering a confinement housing situation (feedlot) with a second vaccination upon arrival to the feedlot.

Treatment Rapid treatment at the first signs of neurologic disease is important in an outbreak but effective treatment is difficult due to the rapid course of the disease.

r. Leptospirosis

Etiology Fourteen different species of the spirochete genus *Leptospira* are now recognized, and pathogenic serovars exist within each species. *Leptospira interrogans* serovars *pomona*, *icterohaemorrhagiae*, *grippotyphosa, interrogans*, and *hardjo* are recognized pathogens. *L. hardjo* and *L. pomona* are the serovars most commonly diagnosed in cattle, with *L. hardjo* the major serovar in sheep. Goats are susceptible to several serovars.

Clinical Signs Acute and chronic infections in cattle are more common than in sheep and goats. Infections in cattle often are subclinical, especially in non-pregnant and non-lactating animals. Acute infection in calves can

be severe and present with high fever, hemolytic anemia, hemoglobinuria, jaundice, and pulmonary congestion; meningitis and death may result. Lactating cows will have severe drops in production. Chronic cases may lead to abortion, with retained placenta, weakened calves or chronic carrier state. Infertility may also be a sequela. Leptospirosis causes similar symptoms in sheep and goats but is relatively uncommon in these species; however, mortality rates of above 50% have been reported in infected ewes and lambs.

Epizootiology and Transmission Leptospires are a large genus making the disease difficult to prevent, treat and control. The organism survives well in the environment, especially in moist, warm, stagnant water. Wild animals often serve as maintenance hosts, but domestic livestock may be reservoirs also. Organisms are shed in the urine, uterine discharges and through the milk. Infection occurs via ingestion of contaminated feed, water, placental fluids, or through the mucous membranes of the susceptible animal. Chronically infected animals may shed the organism in the urine for 60 days or longer.

Necropsy Diagnosis is confirmed by identification of leptospires in fetal tissues. The leptospires are visible in silver- or fluorescent antibody-stained sections of liver or kidney. Leptospires may also be seen under dark-field or phase-contrast microscopy of fetal stomach contents. Serologic testing coupled with immunofluorescence or PCR of urine from a representative sample of cattle aids in diagnosis.

Differential Diagnoses Because of the associated anemia, differential diagnoses should include copper toxicity and parasites in addition to other abortifacient diseases.

Prevention and Control Polyvalent vaccines, tailored to common serovars regionally, are available and effective for preventing leptospirosis in cattle. Immunity is serovar specific. Because serological titers tend to diminish rapidly (within 40–50 days in sheep), frequent vaccination may be necessary.

Treatment Antibiotic treatment is aimed at treating ill animals and trying to clear the carrier state. Vaccination and antibiotic therapy can be combined in an outbreak.

Research Complications Leptospirosis is zoonotic and may be associated with flu-like signs, meningitis or hepatorenal failure in humans.

s. Listeriosis (Circling Disease, Silage Disease)

Etiology *Listeria monocytogenes* is a gram-positive, pleomorphic, motile, non-spore-forming, beta-hemolytic coccobacillus that survives in soil, feeds and other organic materials for long periods of time. The organism is often found in fermented feedstuffs such as spoiled silage. Listeria is a saprophyte and a psychrophile that prefers microaerophilic conditions. See Liu (2009) for information on Listeria.

Clinical Signs Listeriosis is an acute, sporadic, noncontagious disease associated with neurological signs, mastitis or abortions in sheep and other ruminants. The overall case rate is low. Three forms of disease are described: encephalitis, placentitis with abortion, and septicemia with hepatitis and pneumonia. The encephalitic form is most common in ruminants; the symptoms attributable to encephalitis are responsible for the 'circling disease.' The placental form usually results in third-trimester abortions in adult females who typically survive this form of the disease.

Epizootiology and Transmission The organism most commonly is transmitted by ingestion of contaminated feeds and water. When severe outbreaks occur, feedstuffs should be assessed for spoilage. *Listeria* organisms can be shed by asymptomatic carriers, especially at the end of pregnancy and at parturition.

Diagnosis and Necropsy Findings Diagnosis is usually made from clinical signs, confirmed by culture (cold enrichment at 20°C improve success), impression smears of brain or reproductive tissue or tissue fluorescent antibody techniques. Microabscesses of the midbrain with gram-positive bacilli are characteristic of encephalitis.

Differential Diagnoses Rabies, bacterial meningitis, brain abscess, lead toxicity, PEM, and otitis media must be considered as differentials; in sheep, organisms causing abortion, pregnancy toxemia, and enterotoxemia due to *C. perfringens* Type D and in goats, CAE viral infection.

Prevention and Control Affected dams should be segregated and treated. Other animals in the group may be treated with oxytetracycline as needed. Aborted tissues should be removed immediately. Proper storage of fermented feeds minimizes this source of contamination.

Treatment Affected animals should be treated early and aggressively with penicillin (drug of choice) or other antibiotics. Severely affected animals should receive appropriate fluid support and nursing care.

Research Complications *Listeria* can cause mild to severe flu-like signs in humans, and may be a particular risk for pregnant women and older or immune compromised individuals. Listeriosis in humans is a reportable disease.

t. Mastitis

Mastitis in Sheep and Goats Mastitis in ewes and does may be acute, subclinical, or chronic (Kirk and Glenn, 1996). Acute mastitis usually results in abnormal appearance and composition of milk, heat, pain, and swelling in the mammary gland and systemic signs (fever, anorexia). In sheep, *Mannheimia hemolytica* is the most common cause of acute mastitis. In goats,

the primary causative organisms are *Staphylococcus epidermidis* and other coagulase-negative *Staphylococcus* species. Subclinical mastitis is diagnosed by determining somatic cell count in milk, performing a California Mastitis Test or culturing the affected glands. An indication of subclinical mastitis in ewes or does may be thin, poorly growing offspring. Diffuse chronic mastitis or 'hardbag' results from interstitial accumulations of lymphocytes in the udder, usually bilaterally. Redness and swelling are absent. Serological evidence suggests that diffuse chronic mastitis is caused by the retrovirus that causes ovine progressive pneumonia (OPP, Visna/maedi virus) in sheep and the related CAE virus (CAEV) in goats.

Treatment for acute bacterial mastitis should include aggressive application of broad-spectrum antibiotics (intramammary and systemic) and supportive therapy such as fluids and anti-inflammatory drugs. It is necessary to frequently milk out the infected gland; oxytocin injections preceding milking will improve gland evacuation. There is currently no treatment available for diffuse chronic mastitis.

Bovine Mastitis Mastitis is the disease of greatest economic importance for the dairy cattle industry, and a thorough discussion is beyond the scope of this reference. The most common bovine mastitis pathogens include *Staphylococcus aureus*, *Streptococcus agalactiae, Strep*. spp., *Corynebacterium bovis* (summer mastitis of heifers, dry cows, and beef breeds), coliform agents (*E. coli* and *Klebsiella pneumonia*), and *Mycoplasma* spp. including *M. bovis* (California mastitis). Many of these agents can cause acute as well as chronic mastitis and severe systemic dysfunction including fever and anorexia. Symptoms and treatment of mastitis in cattle are similar to those in small ruminants.

There are many interrelated factors associated with prevention and control of mastitis in a herd including herd health and dry cow management, milking procedures and equipment, and the condition of the environment. Teat and udder cleaning practices include washing and drying with single service paper or cloth towels and pre- and post-milking dipping with disinfecting agents. Milking equipment must be maintained to provide proper vacuum levels and pulsation rates. Management of the overall herd includes aspects such as vaccination programs; nutrition; isolation of incoming animals; and quarantine, treatment, or culling of diseased individuals. Culturing or testing newly freshened cows and periodic bulk tank milk cultures help to monitor subclinical mastitis. At the time of dry off, all cows should be treated with intramammary antibiotics. Some chronic infections can be successfully cleared during this time. Younger, disease-free animals should be milked first; any animals with diagnosed problems should be milked after the rest of the herd and/or segregated during treatment. Facilities that provide clean and dry areas for the animals to rest and feed as well as control insect burden will reduce exposures to mastitis pathogens.

u. *Moraxella bovis* (Infectious Bovine Keratoconjunctivitis [IBK] or 'Pinkeye' in Cattle)

Etiology *Moraxella bovis*, a gram-negative coccobacillus causes infectious bovine keratoconjunctivitis (IBK) in cattle. This organism is not a cause of keratoconjunctivitis in sheep and goats. The disease includes conjunctivitis and ulcerative keratitis.

Clinical Signs IBK is characterized by acute onset and rapid course characterized initially by lacrimation, photophobia, and blepharospasm. Conjunctival injection and chemosis develop within a day of exposure, and then keratitis with corneal edema and ulcers. Anterior uveitis may be a sequel within a few days, and thicker mucopurulent ocular discharge may be seen. Corneal vascularization begins by 10 days after onset. Re-epithelialization of the corneal ulcers occurs by 2–3 weeks after onset. Most ulcers will heal without loss of vision, but corneal rupture and blindness can occur in severe cases. Diagnosis is usually based on clinical signs, but culturing is helpful and fluorescein staining is useful for demonstrating corneal ulceration.

Epizootiology and Transmission The disease is more severe in younger cattle. The bacteria are shed in nasal secretions, and cattle may be subclinical carriers. Transmission is by fomites, flies, aerosols, and direct contact. Other factors contributing to infection include ultraviolet light and trauma from dust or plant materials. Incidence is higher in warm weather.

Necropsy Findings Necropsy is not typically performed on these cases.

Differential Diagnoses With *M. bovis* it is important to first determine that the lesions are not due to foreign bodies or parasites. Infectious bovine rhinotracheitis virus causes conjunctivitis but the central corneal ulceration characteristic of IBK is not seen with *M. bovis* infections.

Prevention and Control Available vaccines help to decrease incidence and severity. Other preventative measures include control of insect pests; mowing high pasture grass to minimize ocular trauma; provision of shade; controlling dust and sources of other mechanical trauma; and segregation of animals by age.

Treatment Cattle can recover without treatment, but younger animals should be treated as soon as the infection is detected. Antibiotic treatments include topical and subconjunctival administration. Third-eyelid flaps, temporary tarsorrhaphy, or eye patches often are beneficial.

Research Complications This pathogen presents a research complication due to the carrier status of some animals, the severity of disease in younger animals and

treatment and labor costs associated with infections. The overall condition of the cattle will be affected for several weeks, and permanent visual impairment or loss and ocular disfigurement may occur.

v. Mycobacterial Diseases

i. MYCOBACTERIUM BOVIS *(TUBERCULOSIS)*

Etiology *Mycobacteria* are aerobic, nonmotile, nonspore forming, acid-fast pleomorphic bacilli. Most cases of tuberculosis in sheep are related to *M. bovis* or *M. avium*. Cases in goats have been attributed to *M. bovis*, *M. avium*, or *M. tuberculosis*. *M. bovis* causes tuberculosis in cattle, but also has a wide host range.

Clinical Signs and Diagnosis Tuberculosis is a sporadic, chronic, granulomatous contagious disease of practically all vertebrates including humans. The infection is often asymptomatic and may be diagnosed only at necropsy. The primary sites of infection are the respiratory system (*M. bovis*) and the digestive system (*M. avium*). Other tissues such as mammary tissue and reproductive tract may be involved. Locations of the characteristic tubercles will determine whether clinical signs are seen. Respiratory signs may include dyspnea, coughing, and pneumonia. Digestive tract signs include diarrhea (most commonly), bloat, or constipation. The most important diagnostic test for TB is the intradermal tuberculin test using purified protein derivatives (PPD). Confirmation of diagnosis is achieved by culture or by PCR.

Epizootiology and Transmission *M. bovis* survives for months in the environment, especially in cattle feces. Animals acquire the infection from the environment or from other animals via aerosols, contaminated feed and water, and in secretions such as milk, semen, genital discharges, urine and feces. Subclinically infected animals serve as carriers.

Necropsy Findings Yellow primary tubercles (granulomas) with central areas of caseous necrosis and calcification are present in the lungs. Touch impressions of lesions will have acid-fast bacteria (AFB). Caseous nodules are also associated with gastrointestinal organs and mesenteric lymph nodes.

Prevention and Control The main reservoirs of infection are humans and cattle. Significant progress has been made in eradication programs in the United States during the past several decades but infected animals continue to be found, particularly in captive deer herds and along the southern border with Mexico. Notification of state officials is required following identification of intradermal-positive animals. Great care must be exercised in any tissue handling or necropsies of reactors, and state animal health officials should be consulted regarding disposal of materials and cleaning of premises following depopulation of positive animals.

Treatment Treatment is usually not allowed due to the zoonotic potential, chronicity of the disease, and the treatment costs. Slaughter is required to prevent potential transmission to humans.

Research Complications The pathogen is zoonotic. Identification will result in quarantine of facilities.

*ii. PARATUBERCULOSIS (*M. AVIUM *SUBSPECIES* PARATUBERCULOSIS*; JOHNE'S DISEASE)*

Etiology *Mycobacterium avium subspecies paratuberculosis*, the causative agent of Johne's disease, is a fastidious, nonspore forming, acid-fast, gram-positive rod. The organism is a subspecies of *M. avium*.

Clinical Signs and Diagnosis Johne's disease is a chronic, contagious, granulomatous disease of adult ruminants characterized by unthriftiness, weight loss, and intermittent diarrhea. The incubation period is long and infected cattle can appear healthy for months to years. Milk production may fall or fail to reach expected levels. In sheep and goats, chronic wasting is usually observed with only occasional pasty (cow-pat) feces or diarrhea, usually only in advanced disease. Although clinical signs are nonspecific, Johne's should be considered if the diarrheic animals have a good appetite and are on a good anthelmintic program.

The three main areas of focus for testing are (1) detection of the organism in feces or tissue by culture or PCR; (2) evidence of cellular immune response to infection by skin or interferon-γ testing; and (3) detection of antibody to *M. paratuberculosis* by ELISA or AGID (Sergeant *et al.*, 2003). *Post-mortem* testing at necropsy with culture and histopathology on multiple tissues remains the gold standard for definitive diagnosis. The ELISA tests are the most sensitive and specific and should be used to determine the prevalence of infection within a herd of cattle. See the Johne's information center (http://www.johnes.org; Robbe-Austerman (2011)) for additional information on Johne's disease in various species.

Epizootiology and Transmission The organism is prevalent in the environment and most commonly is transmitted to young animals by ingestion of milk or by direct or indirect contact. Cattle exposed as adults are less likely to become infected. It is important to note that fecal shedding occurs before exhibiting clinical signs, therefore making the 'silent' stage of infection an important source of transmission.

Necropsy and Diagnosis The ileum from infected cattle is grossly thickened; but this is not seen in sheep or goats. Ileal and ileocecal lymph nodes provide the best samples for histology and acid fast staining.

Differential Diagnoses Other diseases causing chronic wasting and poor body condition include chronic salmonellosis, severe parasitism, lentiviruses in small ruminants, and pyelonephritis.

Treatment Treatment is not worthwhile.

Prevention and Control Prevention is the most effective method to manage this pathogen. Efforts

should be focused on eliminating the disease through test and slaughter, and on breaking the chain of transmission to neonates. Calves should be removed from the dam immediately, fed pasteurized colostrum from a bottle and then raised separate from adult cattle until 1 year of age. Prolonged survival in the soil (up to 1 year) and wildlife reservoirs (hares) can make control of established infections challenging.

Other Considerations *Mycobacterium avium* subspecies *paratuberculosis* is being investigated as a factor in the development of Crohn's disease in humans. However, there remains no evidence of zoonotic potential.

w. Navel Ill (Omphalitis, Omphalophlebitis, Omphaloarteritis, Joint Ill)

Etiology The most common organism causing infection of the umbilicus is *Trueperella* (formerly *Actinomyces, Corynebacterium*) *pyogenes*; other bacteria may be present. *Arcanobacterium* are anaerobic, non-motile, nonspore forming, gram-positive, pleomorphic rods to coccobacilli. Other environmental contaminants associated with this disease include *E. coli*, *Enterococcus* spp., *Proteus*, *Streptococcus* spp., and *Staphylococcus* spp.

Clinical Signs and Diagnosis Navel ill is an acute localized inflammation and infection of the external umbilicus. Animals present with fever, painful enlargement of the umbilicus, varying degrees of depression and anorexia. Purulent discharges may be seen draining from the umbilicus. Involvement of the urachus is usually followed by cystitis and associated signs of dysuria, stranguria, and hematuria. Other common severe sequelae include septicemia, pneumonia, peritonitis, septic arthritis (joint ill), patent urachus and urachal abscesses, umbilical hernias, meningitis, osteomyelitis, uveitis, endocarditis, and diarrhea.

Epizootiology and Transmission Many cases occur in neonates and most cases occur within the first 3 months of age. Cleanliness of the birthing or housing environment and successful transfer of passive immunity are important factors in the occurrence of the disease.

Diagnosis Navel ill is diagnosed by typical clinical signs and should always be considered for young ruminants during the first week of life with fever of unknown origin and for slightly older lambs, kids, or calves that are not thriving.

Differential Diagnosis The major differential is an umbilical hernia which will typically not be painful and infected and can often be reduced.

Treatment Omphalitis can be treated with a 10- to 14-day course of broad-spectrum antibiotics such as ampicillin, ceftiofur, florfenicol, or erythromycin. If an isolated abscess is palpable, it should be surgically opened and repeatedly flushed with iodine solutions. The prognosis for recovery is good if systemic involvement has not occurred.

Prevention and Control The disease is best prevented and controlled by providing clean birthing environments, ensuring adequate colostral immunity, and dipping the umbilicus of newborns with tincture of iodine or strong iodine solution.

Research Complications The disease can be costly to treat and the toll taken on the young animals due to the consequences of systemic infection may detract from their research value.

x. Pasteurellosis (Shipping Fever, Hemorrhagic Septicemia, Enzootic Pneumonia)

i. **MANNHEIMIA HAEMOLYTICA, PASTEURELLA MULTOCIDA, HISTOPHILUS SOMNI**

Etiology *Mannheimia haemolytica* and *Pasteurella multocida* are aerobic, nonmotile, nonspore-forming, bipolar, gram-negative rods, associated with pneumonia and septicemia in all ruminants.

Clinical Signs Pasteurellosis is an acute bacterial disease characterized by bronchopneumonia, septicemia, and sudden death. The organism invades the mucosa of the gastrointestinal or respiratory tract and causes localized areas of necrosis, hemorrhage, and thrombosis. The lungs and liver are frequent locations for formation of microabscesses. Acute rhinitis or pharyngitis often precedes the respiratory form. The organism also may invade the bloodstream causing disseminated septicemia. Animals may exhibit nasal discharge of mucopurulent to hemorrhagic exudate, hyperthermia, coughing, dyspnea, anorexia, and depression. With the respiratory form, auscultation of the thorax suggests dullness and consolidation of anteroventral lobes that will be confirmed by radiographs. The disease is diagnosed by clinical signs, blood cultures from septicemic animals, blood smears showing bipolar organisms, and history of predisposing stressors.

Epizootiology and Transmission The organism is ubiquitous in the environment and in the respiratory tract. Younger ruminants, between 2 and 12 months of age, are especially prone to infection during times of stress such as weaning, transportation, dietary changes, weather changes, and overcrowding. The pneumonic form appears as a component of BRDC associated with concurrent infections such as parainfluenza-3, BRSV, and in cattle, bovine herpes virus 1 or BVDV. The organism is transmitted between animals by direct and indirect contact through inhalation or ingestion.

Necropsy Findings With the pneumonic form, serofibrinous exudates fill the alveoli and ventral lung lobes are consolidated, congested and purple–gray in color. Degenerate streaming leukocytes (oat cells) are pathognomonic for *M. haemolytica*. Fibrinous pleuritis, pericarditis, and hematogenously induced arthritis also may be evident as well as areas of necrosis and hemorrhage in the small intestines and multifocal lesions on the surface of the liver.

Pathogenesis Stress and concurrent viral infection are considered to be key factors in the pathogenesis of *M. haemolytica* and *Pasteurella* infections. Macrophages and neutrophils are lysed by bacterial leukocidin as they arrive at the lung, and enzymes released by phagocytes cause additional damage to lung tissue.

Differential Diagnosis *Mycoplasma bovis* pneumonia.

Treatment Treatment includes the use of antibiotics and anti-inflammatories. In outbreaks, cultures from fresh necropsies are helpful for determining sensitivities useful for the remaining group.

Prevention and Control The incidence of disease can be decreased by minimizing sources of stress and by vaccinating for viral respiratory pathogens. *M. haemolytica-P. multocida* bacterins labeled for cattle, sheep, and goats are available. Passive immunity is protective in young animals. Preventative measures include maintaining good ventilation in enclosures and barns and metaphylaxis of at-risk animals with approved drugs.

y. Salmonellosis

Etiology *Salmonella enterica* is a motile, aerobic to facultatively anaerobic, nonspore-forming, gram-negative bacillus and is a common inhabitant of the gastrointestinal tract of ruminants. The genus *Salmonella* contains two species, *S. bongori* which infects mainly poikilotherms and rarely, humans, and *S. enterica* which includes approximately 2500 serovars and are a major cause of food-borne illness in humans. *Salmonella* are properly designated using their serovar (which was often formerly a species name), so, for example, *S. enterica* subsp. *enterica* serovar Typhimurium (aka *S.* Typhimurium) and serovar Enteritidis (*S.* Enteritidis). The organism is associated with enteric disease and abortions. The most common serovars in animals (as reported to the CDC) are *S.* Typhimurium, *S.* Newport, *S.* Agona, *S.* Heidelberg; *S.* Dublin and *S.* Abortusovis have been implicated with bovine and ovine abortions (Center for Food Security and Public Safety, 2005).

Clinical Signs and Diagnosis Salmonellosis causes acute gastroenteritis, dysentery, and septicemia in all domestic ruminants; feces may contain mucous and/or blood and have a distinctive, 'septic tank' odor. The animals are anorexic and hyperthermic and become severely depressed and weak, losing a high percentage of their body weight. Animals may die in 1–5 days due to dehydration associated with dysenteric fluid loss, septicemia, shock, and acidosis. Morbidity may be 25%, and mortality may reach 100%. Morbidity and mortality will be highest in neonates and some may simply be found dead. Septicemia may result in subsequent meningitis, polyarthritis, and pneumonia. Chronically infected animals may have intermittent diarrhea.

Salmonella may cause abortions in sheep, goats, and cattle throughout gestation. Hemorrhage, placental necrosis, and edema will be present. Metritis and placental retention may occur. Some mortality of dams may occur.

Diagnosis is based on clinical signs, and can be confirmed by culturing fresh feces or at necropsy. Because shedding of organisms is intermittent, repeated cultures are recommended. Leukopenia and a degenerative left shift are common hematological findings.

Epizootiology and Transmission Stresses associated with recent shipping, overcrowding, and inclement weather may predispose the animal to enteric infection. Birds and rodents may be natural reservoirs of *Salmonella* in external housing environments. Transmission is fecal–oral. Animals that survive may become chronic carriers and shedders of the organisms and this has been demonstrated experimentally.

Necropsy Findings and Diagnosis Animals will have noticeable perineal staining. Intestines (particularly the ileum, cecum, and colon) contain mucoid feces with or without hemorrhages. Petechial hemorrhages and areas of necrosis may be noticed on the surface of the liver, heart, and mesenteric lymph nodes. The wall of the intestines, gall bladder, and mesenteric lymph nodes will be edematous; and a pseudodiphtheritic membrane lining the distal small intestines and colon may be observed in cattle and sheep. Splenomegaly may be present. Necrosuppurative inflammation of the Peyer's patches is characteristic. Fibrinous cholecystitis is considered pathognomonic.

Pathogenesis After ingestion, the organism proliferates in the intestine. Bacteria are selectively taken up by the M cells of the Peyer's patches and gut-associated lymphoid tissue. Damage to the intestines and the resulting diarrhea are due to the bacterial production of cytoxin and endotoxin. Although the *Salmonella* organisms will be taken up by phagocytic cells involved in the inflammatory response, they survive and multiply further. Septicemia is a common sequel with the bacteria localizing throughout the body.

Differential Diagnoses In young animals, differentials include other enteropathogens such as *E. coli*, rotavirus and coronavirus, clostridial infections, cryptosporidiosis, and coccidiosis. These pathogens may also be present in the affected animals. Differentials in adults include bovine viral diarrhea and winter dysentery in cattle, and parasitemia and enterotoxemia in all ruminants.

Prevention and Control Affected animals should be isolated during herd outbreaks. Samples for culture should include herdmates, water and feed sources, recently arrived livestock (including other species), and area wildlife including birds and rodents. Culling carrier animals, pest control, and intensive cleaning and disinfection of facilities are all important during outbreaks.

Treatment Nursing care includes rehydration and correction of acid–base abnormalities. Antibiotic therapy may be useful in cases with septicemia, but the use of oral antibiotics is controversial because it may induce carrier animals.

Research Complications Salmonellosis is zoonotic, and some serotypes of the organism have caused fatalities even in immunocompetent humans.

z. Tularemia

Etiology Tularemia is caused by *Francisella tularensis*, a nonmotile, nonspore-forming, aerobic, gram-negative, rod-shaped bacterium.

Clinical Signs and Diagnosis Sheep are most commonly affected. The disease is characterized by hyperthermia, muscular stiffness, and lymphadenopathy. Anemia and diarrhea may develop, and infected lymph nodes enlarge and may ulcerate. Mortality may reach 40%. Diagnosis is confirmed by prompt culturing of the organism from lymph nodes, spleen, or liver where granulomatous lesions form; serological findings may also be helpful.

Epizootiology and Transmission The disease is most commonly transmitted by ticks or biting flies. The wood tick, *Dermacenter andersoni*, is an important vector in transmitting the disease in western states; wild rodents and rabbits serve as natural reservoirs. The organism can also be transmitted orally through contaminated water.

Necropsy Findings Suppurative, necrotic lymph nodes are typical. Lungs will be congested and edematous. Necrosuppurative splenitis.

Treatment Infected animals can be treated with oxytetracycline, aminoglycosides, or cephalosporins.

Differential Diagnoses When tick infestations are heavy, *F. tularensis* should be suspected. *Mannheimia hemolytica* (sheep), *Histophilus somni* (cattle), and *Mycoplasma mycoides* (goats), and anthrax (all ruminant species) should be considered as differentials.

Prevention and Control Eliminating the tick vectors and deer flies can prevent tularemia.

Research Complications The disease is zoonotic and transmission to people may result from tick or fly bites or from handling contaminated tissues. This is a USDA reportable disease.

aa. Mycoplasmal Diseases

***i.* MYCOPLASMA BOVIGENITALIUM, MYCOPLASMA BOVIS**

Etiology *M. bovigenitalium* and *M. bovis* are associated sporadically with bovine infertility and abortions. Mycoplasma bovis is a significant respiratory pathogen. This pathogen has also been reported associated with similar clinical signs in sheep and goats.

Clinical Signs and Diagnosis Infertility is more commonly caused by *M. bovigenitalium* infections and granular vulvovaginitis and endometritis will be present. Granular vulvovaginitis is characterized by raised papules on the mucous membranes and mucopurulent exudate. Abortions and mastitis are associated with *M. bovis* infections. Calves that are born may be weak. *M. bovis* is a big economic concern in beef and dairy and has been called an 'all purpose pathogen' causing acute and chronic arthritis, middle and inner ear infections, acute and chronic pneumonia, and mastitis.

Epidemiology and Transmission Mycoplasmal species are considered ubiquitous, are carried in the genital tracts of males and females, and are transmitted during natural breeding or through contaminated insemination materials. Transmission occurs by aerosol, by passage through the birth canal, by direct contact, and by contamination from urine of infected animals. Feeding unpasteurized milk (particularly waste milk) to dairy calves is a major risk factor.

Treatment Fluoroquinolone, oxytetracycline, tilmicosin, and tulathromycin antibiotics may be useful for treating *Mycoplasma*-induced reproductive diseases. Prevention is far more rewarding than treatment.

ii.* MYCOPLASMA OVIPNEUMONIAE *(OVINE MYCOPLASMAL PNEUMONIA)

Etiology *Mycoplasma ovipneumoniae* causes acute or chronic pneumonia in lambs.

Clinical Signs *Mycoplasma* induces serious diseases in sheep causing acute and chronic pneumonia, conjunctivitis, and genitourinary disease. The disease may be coincidental with pasteurellosis. Respiratory distress, coughing and nasal discharge are observed in infected animals. Bronchoalveolar lavage followed by culture is the best method for diagnosis; however, Mycoplasmas are fastidious organisms requiring special handling techniques. Mycoplasmas are isolated from the genitourinary tract of sheep. Vulvovaginitis and reproductive problems are associated conditions.

Treatment Tylosin, quinolones, oxytetracycline, and gentamicin are good choices for therapy.

iii.* M. MYCOIDES *BIOTYPE F38 (CONTAGIOUS CAPRINE PLEUROPNEUMONIA, CAPRINE PNEUMONIA, PLEURITIS, AND PLEUROPNEUMONIA)

Etiology *M. mycoides* biotype F38 is the agent of contagious caprine pleuropneumonia and is found worldwide. In the United States, caprine pneumonia is also caused by *M. ovipneumoniae*, *M. mycoides* subspecies *capri*, and *M. mycoides* subspecies *mycoides* (Large Colony Type).

Clinical Signs Contagious Caprine Pleuropneumonia is characterized by severe dyspnea, nasal discharge, cough, and fever. Infections with other *Mycoplasma* species also have similar clinical signs.

Epizootiology and Transmission This disease is highly contagious, with high morbidity and mortality. Transmission is by aerosols. *M. mycoides* subspecies *mycoides* has become a serious cause of morbidity and mortality of goat kids in the United States.

Necropsy Large amounts of pale straw-colored fluid and fibrinous pneumonia and pleurisy are typical. Some lung consolidation may be present. Meningitis, fibrinous pericarditis, and fibrinopurulent arthritis may also be found. Organisms may be cultured from lungs and other internal organs.

Differential Diagnosis In the United States, the principal differential for *M. mycoides* subspecies *mycoides* is CAE.

Treatment Tylosin and oxytetracycline are effective. Some infections are slow to resolve.

Prevention and Control Vaccines are available in some areas. Infected herds are quarantined. New goats should be quarantined before introduction to the herd.

Research Complications The worldwide distribution of the F38 biotype, potential for aerosol transmission and high morbidity and mortality of Mycoplasmal infections make them economically important diseases in goats. Chronic subclinical infections can result in anesthetic complications in sheep.

iv. MYCOPLASMA CONJUNCTIVAE *(MYCOPLASMAL KERATOCONJUNCTIVITIS)*

Etiology *M. conjunctivae* and other species cause infectious conjunctivitis or pinkeye in sheep and goats with associated hyperemia, edema, lacrimation, and corneal lesions. Respiratory disease and other infections, such as mastitis, may also be observed.

Clinical Signs and Diagnosis All ages of animals may be affected. Initially, lacrimation, conjunctival vessel injection, then keratitis and neovascularization are seen. Sometimes uveitis is evident. The presentation is usually unilateral, and recurring infections are common.

Epizootiology and Transmission The infection is passed easily between animals by direct contact. Animals can become reinfected and carrier animals may be a factor in outbreaks.

Necropsy It is unlikely animals would undergo necropsy for this problem.

Differential Diagnoses The primary differential in sheep and goats is *Chlamydophila*, as well as *Branhamella, Rickettsia (Colesiota) conjunctivae*, and IBR in goats only.

Treatment Animals recover spontaneously within about 10 weeks. Tetracycline ointments and powders are also used. Third eyelid flaps may be necessary if corneal ulceration develops.

Prevention and Control New animals should be quarantined, and if necessary treated, before introduction to the flock or herd.

v. MYCOPLASMA MASTITIS

Etiology and Transmission *Mycoplama* spp. can spread from cow to cow via aerosol transmission. Prior to bacteremia, the pathogen is spread during milking by milker's hands or the milking unit. The bacteria are spread in the milk in large numbers before clinical signs appear and very few organisms are required to infect a quarter. Infected cows may have normal somatic cell counts (SCCs), therefore a cow may be asymptomatic with a normal SCC and serve as a source of infection for other cows.

Clinical Signs and Diagnosis Initial presentation is a swollen quarter that is sensitive to the touch and has decreased milk production. Abnormal milk generally develops 1–3 days later. The milk initially will have visible particles that progress to puss and eventually become watery. Affected cows do not appear sick and maintain good appetites. Generally more than one quarter is infected and it will often invade quarters that are already infected with another organism. Cows that have recovered from the clinical presentation generally always have a subclinical infection.

Necropsy This disease does not generally result in death.

Diagnosis Mycoplasma should be suspected if there are an increase number of clinical cases of mastitis that are nonresponsive to therapy. Diagnosis is made by culturing the organism from the milk. Normal milk culture media will not grow the bacteria from the milk, so *Mycoplasma* must be specifically requested. Considering cows are generally infected with other pathogens as well, this can complicate and delay diagnosis.

Treatment There is no effective treatment for *Mycoplasma mastitis*. If other organisms are cultured from the milk, those should be treated. If the cow has a good immune health status, she may eventually eliminate the infection. Cows may develop normal milk, but still be subclinically infected and therefore shedding the bacteria into the next lactation.

Prevention and Control Screen new animals before they enter the milking herd. Three to five negative individual cow or bulk tank cultures is highly recommended.

ab. Rickettsial Diseases

i. Q OR QUERY FEVER (COXIELLA BURNETII)

Etiology *C. burnetii* is a small, gram-negative, obligate intracellular organism. It is the etiologic agent of Query Fever, or Q Fever (Queensland fever, nine-mile agent), and is regarded as a major cause of late abortion in sheep. Historically considered a Rickettsial organism, it now is thought to be more closely related to *Legionella* and *Francisella* than to *Rickettsia* (Merck Veterinary Manual Online, 2011).

Clinical Signs Infection of ruminants with *C. burnetii* is usually asymptomatic. Experimental inoculation

in other mammals has resulted in transient hyperthermia, mild respiratory disease, and mastitis. Abortions, stillbirths, and births of weak lambs are also seen.

Epizootiology and Transmission *C. burnetii* is extremely resistant to environmental changes as well as disinfectants; persistence in the environment for a year or longer is possible. The organism is associated with either a free-living or an arthropod-borne cycle. Although several tick species may serve as vectors, *Coxiella* may be maintained without a tick intermediate. The organism is especially concentrated in placental tissues, and reproductive fluids. The organism also is shed in milk, urine, feces, and oronasal secretions. Placenta can contain up to 10^9 human ID_{50} per gram. The infectious dose for humans can be as low as a single organism, and bacteria can spread up to 11 miles in the wind. The organism can persist in the environment for months.

Necropsy Findings No specific lesion will be seen in aborted or stillborn fetuses but necrotizing placentitis will be a finding in cases of abortion. The placenta will contain white chalky plaques and a red–brown exudate. Intracytoplasmic organisms within trophoblasts are characteristic. The organism stains red with modified Ziehl–Neelsen and Macchiavello stains and purple with Giemsa stain.

Differential Diagnoses Specific diagnosis of Q fever is based upon detection of antibodies. Within 2–3 weeks post-infection, immunoglobulin M (IgM) and IgG antiphase II antibodies against *C. burnetii* are detected. The presence of IgG antiphase I C. burnetii antibodies at titers of ≥1:800 by microimmunofluorescence is indicative of chronic Q fever (Maurin and Raoult, 1999). PCR of genital swabs, milk, and fecal samples also has been used (Maurin and Raoult, 1999; Merck Veterinary Manual Online, 2011; Van Metre, 1996). Because of the risk of laboratory acquired infection, culture is not recommended.

Treatment *Coxiella* can be treated with oxytetracyclines. Vaccines for ruminants are not commercially available in the United States.

Prevention and Control Any aborting animals should be segregated from other animals, and other pregnant animals treated prophylactically with tetracycline. Serologic screening of ruminant sources should be performed routinely. Barrier housing, a review of ventilation exhaust, and defined handling procedures are often required. All placentas and all aborted tissues should be handled and disposed carefully. Q Fever has been reported in many mammalian species, including cats.

Research Complications *C. burnetii*-free animals are particularly important in studies involving fetuses and placentation. Because of its zoonotic potential, *C. burnetii* presents a unique problem in the animal research facility environment. Of greatest concern are risks to immunocompromised individuals, pregnant women, other animals, and the presence of carrier animals that may shed the organism in the placenta. *C. burnetii* is considered a select agent. Readers are referred to the Center for Disease Control (CDC) and Animal and Plant Inspection Services (APHIS) National Select Agent Registry (http://www.selectagents.gov) for additional information as well as an excellent review on Q Fever (Maurin and Raoult, 1999; Van Metre, 1996).

2. *Viral/Chlamydophilal*

a. Viral Diseases

i. BLUETONGUE (REOVIRIDAE)

Etiology The bluetongue virus is an RNA virus in the genus *Orbivirus*, and family Reoviridae. Twenty-six serotypes have been identified, with 15 from the United States. Bluetongue is an acute arthropod-borne viral disease of ruminants characterized by stomatitis, depression, coronary band lesions and congenital abnormalities (Bulgin, 1986). It is mostly found in western states.

Clinical Signs and Diagnosis Sheep are the most likely to show clinical signs. Clinical disease is less common in goats and cattle. Early in the infection, animals will spike a fever, and will develop hyperemia and congestion of tissues of the mouth, lips, and ears. The virus name, bluetongue, is associated with the typical cyanotic membranes. The fever may subside; but tissue lesions erode causing ulcers. Increased salivary discharges and anorexia are often related to ulcers of the dental pad, lips, gums, and tongue, although salivation and lacrimation may precede apparent ulceration. Chorioretinitis and conjunctivitis are also common signs in cattle and sheep; lameness, skin lesions such as drying and cracking of the nose and mammary gland, and alopecia are also observed. Secondary bacterial pneumonia may occur, and animals may develop severe diarrhea. Sudden deaths may occur due to cardiomyopathy at any time during the disease. Hematologically, animals will be leukopenic. The course of the disease is about 2 weeks and mortality may reach 80%.

If animals are pregnant, the virus crosses the placenta and causes central nervous system lesions. Abortions may occur at any stage of gestation in cattle. Prolonged gestation may result from cerebellar hypoplasia and lack of normal sequence to induce parturition. Cerebellar hypoplasia will also be present in young born of infected dams as well as hydrocephalus, cataracts, gingival hyperplasia, or arthrogryposis.

Diagnosis is based on characteristic clinical signs and confirmed by virus isolation on blood collected during the febrile stage of the disease or brain tissue is collected from aborted fetuses. Fluorescent antibody tests, ELISA, virus neutralization tests, PCR, and Agar gel immunodiffusion (AGID) tests may be used to confirm the diagnosis.

Epizootiology and Transmission The disease is most common in outdoor-housed animals in the western United States. The virus is primarily transmitted by biting midges, *Culicoides*. A combination of factors associated with viral strain, available and susceptible hosts, environmental conditions (such as damp areas where flies breed), and vector presence are factors in the severity of outbreaks. Some sheep breeds such as Charolais and Merino may be more susceptible. Direct contact, virus-contaminated semen or other animal products, or transplacental transfer are other possible but not common means of transmission.

Necropsy Findings At necropsy, erosive lesions may be observed around the mouth, tongue, palate, esophagus, and pillars of the rumen. Ulceration or hyperemia of the coronary bands may also be seen. Many of the internal organs will contain surface petechial and ecchymotic hemorrhages. Subintimal hemorrhages of the large pulmonary arteries are nearly pathognomonic.

Pathogenesis After entering the host, the virus causes prolonged viremia. The incubation period is 6–14 days. The virus migrates to and attacks the vascular endothelium. The resulting vasculitis accounts for the lesions of the skin, mouth, tongue, esophagus and rumen, and the edema often found in many tissues.

Differential Diagnoses Differentials include other infectious vesicular diseases such as foot-and-mouth disease, contagious ecthyma, bovine virus diarrhea, mucosal disease, infectious bovine rhinotracheitis virus, bovine papular stomatitis, and malignant catarrhal fever.

Prevention and Control Modified live vaccines are available in some parts of the United States but should not be used in pregnant animals. Congenital defects are more common from vaccine use than from naturally occurring infection. Vaccinating lambs and rams in an outbreak is worthwhile. Minimizing exposure to the vector in endemic areas will decrease the incidence of the disease.

Treatment Supportive and nursing care is helpful including gruels or softer feeds, easily accessed water and shaded resting places. Nonsteroidal anti-inflammatory drugs are often administered.

Research Complications This is a reportable disease because clinical signs resemble foot and mouth disease and other exotic vesicular diseases.

ii. ENZOOTIC BOVINE LYMPHOMA (BOVINE LEUKEMIA VIRUS, BOVINE LEUKOSIS)

Etiology The term 'bovine lymphosarcoma' may refer to either sporadic lymphoproliferative disease affecting young cattle (juvenile, thymic, or cutaneous) as well as diseases of older cattle which are associated with bovine leukemia virus infection. BLV is a B lymphocyte-associated member of the genus *Deltaretrovirus* (Johnson and Kaneene, 1993a,b,c,d; Rodriguez *et al.*, 2011) which integrates into host target cell DNA by means of the reverse transcriptase enzyme, creating a provirus.

Clinical Signs Only the adult or enzootic form of bovine lymphoma is associated with BLV infection. The majority of animals will not develop any malignancies or clinical signs of infection, and will simply remain permanently infected; approximately 30% will have an elevated peripheral lymphocyte count and subtle immune defects (persistent lymphocytosis). Less than 5% of infected animals develop B cell lymphoma. Clinical signs are loss of condition and a drop in production of dairy cattle, anorexia, diarrhea, ataxia, melena due to bleeding abomasal ulcer, paresis, and other signs dependent on the location of the neoplastic lesions. Tumors will be associated with lymphoid tissues. Common sites include the abomasum, extradural spinal canal, and uterus. Cardiac tumors develop at the right atrial or left ventricular myocardium, and associated beat and rate abnormalities may be ausculted. The common ocular manifestation of the disease is exophthalmus due to retrobulbar masses.

Diagnosis is based on the animal's age, clinical signs, serology, aspirates or biopsies of masses, and necropsy findings. Kits are available for running AGID for which the BLV antigens gp-51 and gp-24 are used; antibodies may be detected within weeks after exposure and may also help in predicting disease in clinically normal cattle. Serology is the most reliable method for diagnosis of BLV although PCR is also used. Most countries recognize AGID as the official import/export test, and ELISA is the most common test for routine diagnostic use. However, serology is unreliable in calves that have ingested colostrum from BLV-positive cows due to passive transfer of antibodies. In addition, the majority of seropositive animals never develop clinical signs.

Epizootiology and Transmission This disease is present worldwide. It is estimated that at least 50% of the cattle in the United States are infected with BLV (USDA, 2007). As few as 1% of these develop lymphoma, but the adult form of the disease described here is the most common bovine neoplastic disease in the United States. In addition to the presence of BLV, the individual's BoLA genotype confers resistance or susceptibility and affects the course of the disease. Transmission is believed to be by inhalation of BLV in secretions; *in utero* or by colostrum; horizontally by contaminated equipment; by rectum during rectal exams or procedures and by breeding bulls during natural service.

Necropsy Findings Tumors may be local or widely distributed; definitive diagnosis of neoplastic tissue specimens is by histology.

Prevention and Control Development and maintenance of a BLV-free herd, or controlling infection within a herd, requires financial and programmatic commitments: BLV-positive and BLV-negative animals maintained

separately; repeated serologic testing; single-use needles; washing and disinfecting instruments (including tattoo devices), needles, and other equipment between animals. A fresh rectal exam sleeve and lubricant should be used for each animal examined. Calves should be fed colostrum from serologically negative cows; however, the protective effect of colostral antibody outweighs the risk of infections. Replacing colostrum with a high-quality colostrum replacer can also be considered.

Treatment Treatment regimens of corticosteroids or cancer chemotherapeutic agents provide only short-term improvement.

Research Complications Many U.S. states and several countries, including Australia, New Zealand, and some countries in Europe have official programs for eradication of enzootic bovine leukosis. BLV is closely related to human T-lymphotropic virus type I (HTLV-1), and aspects of the biology and epidemiology of BLV may be relevant in the study of the human virus.

iii. BOVINE HERPES MAMMILLITIS (BOVINE HERPES 2 VIRUS, BOVINE ULCERATIVE MAMMILLITIS)

Etiology Bovine herpes 2 virus causes bovine herpes mammillitis, a widespread disease characterized by acute ulcerative teat and udder lesions as well as oral and skin lesions.

Clinical Signs and Diagnosis Lesions begin suddenly with teat swelling, tenderness and edema. Lesions progress to vesicles then ulcers; these may take 10 weeks to heal. Lesions may extend to the skin of the udder. Affected cows often resist milking, leading to development of mastitis. Secondary mastitis may also occur due to bacteria associated with the scabs. Diagnosis is by clinical signs and confirmed by histopathology or by virus isolation.

Epizootiology and Transmission The virus is reported to be widespread. Occurrence is often seasonal and biting insects may be vectors. Transmission with successful infection requires deep penetration of the skin. Transmission may be by contaminated milker hands, contaminated equipment, and other fomites.

Differential Diagnoses These include other diseases that cause lesions on teats such as pseudocowpox, papillomatosis, vesicular stomatitis and foot-and-mouth disease virus (FMDV).

Prevention and Control Established milking hygiene practices are important control measures: milkers' handwashing with germicidal solutions or wearing gloves, cleaning equipment between animals, and separating affected animals.

Treatment There is no treatment, and affected animals should be separated from the herd and milked last. Lesions can be cleaned and treated with topical antibacterials.

iv. BOVINE VIRUS DIARRHEA AND MUCOSAL DISEASE COMPLEX

Etiology BVDV is a pestivirus of the Flaviviridae family. A broad range of disease and immune effects is produced by BVDV in cattle but recent reports suggest that other ungulates (including pigs, sheep, and goats) also are susceptible. In addition, this virus is important in the etiology of BRDC, one of the most economically important and complex diseases of cattle. Strains of the BVDV are characterized as cytopathic (CP) and noncytopathic (NCP) based on cell culture growth characteristics. The virus has also been categorized as type 1 and type 2 isolates (along with subgenotypes 1a, 1b, etc.). Heterologous strains exist that may confound even sound vaccination programs.

Clinical Signs and Diagnosis Clinical signs of BVDV infections include abortions, congenital abnormalities, reduced fertility, immunosuppression, and acute and fatal disease. The presence of antibodies, whether from passive transfer or immunizations, does not necessarily guarantee protection from the various forms of the disease.

An acute form of the disease, caused by type 2 BVDV, occurs in cattle without sufficient immunity. After an incubation period of 5–7 days, clinical signs include fever, anorexia, oculonasal discharge, oral erosions, and diarrhea. The disease course may be shorter with hemorrhagic syndrome and death can occur within 2 days. Clinical signs of BVDV in calves also include severe enteritis and pneumonia.

When susceptible cows are infected *in utero* from gestational days 50–100, abortion or stillbirth result. Congenital defects caused by BVDV during gestational days 90–170 include thymic atrophy, cerebellar hypoplasia, ocular defects, alopecia or hypothrichosis, and hydrocephalus. Typical signs of cerebellar dysfunction in calves include wide-based stance, weakness, opisthotonus, hypereflexia, hypermetria, nystagmus, or strabismus. Some severely affected calves will not be able to stand.

Fetuses infected *in utero* also may be normal at birth, or be immunotolerant to the virus and persistently infected (PI). Many PI animals do not survive to maturity, and those that do may have weakened immune systems. The PI animals are important because these animals shed virus throughout their lives, serving as a major source of new infections within the herd, and may develop mucosal disease (MD) caused by a CP BVDV strain. These MD clinical signs include fever, anorexia, and profuse diarrhea that may include blood and fibrin casts, oral and pharyngeal erosions, as well as erosion at the interdigital spaces and on the teats and vulva. Associated clinical signs include anemia, thrombocytopenia, and leucopenia. Secondary effects of hemorrhage and dehydration also contribute to the morbidity and mortality. Animals

that do not succumb to the disease will be chronically unthrifty, debilitated, and infection prone.

Diagnosis is based on herd health history, clinical signs, viral culturing, PCR, or serology. Serology must be interpreted with the awareness of the possibility of persistently infected immunotolerant animals. Identifying PI calves is most commonly done by IHC of skin biopsies (ear notching) or blood.

Epizootiology and Transmission BVDV is present throughout the world. Transmission occurs easily by direct contact between cattle, from feed contaminated by secretions, feces, or aborted fetuses and placentas, and fomites such as contaminated boots, clothing, and equipment. Persistently infected females transmit the virus to their fetuses. Semen can also be a source of virus.

Necropsy Findings *In utero* affected calves may have cerebellar hypoplasia. Older animals may have areas of intestinal necrosis and erosions found from the oral cavity throughout the gastrointestinal tract to the cecum. Respiratory tract lesions will often be complicated by secondary bacterial pneumonia. When the hemorrhagic syndrome develops, petechiation and mucosal bleeding will be present.

Differential Diagnoses Differentials for enteritis of calves include viral infections, *Cryptosporidia*, *E. coli*, *Salmonella*, and *Coccidia*. *Salmonella*, winter dysentery, Johne's disease, intestinal parasites, and malignant catarrhal fever (MCF) are differentials for the diarrhea seen in the disease in adult animals. Respiratory tract pathogens such as BRSV, *Mannheimia*, *Pasteurella*, *Histophilus*, and *Mycoplasma* must be considered for the respiratory tract manifestations. Oral lesions are also produced by MCF, FMDV, vesicular stomatitis, bluetongue and papular stomatitis. Infectious bovine herpesvirus 1, leptospirosis, brucellosis, trichomoniasis, and mycosis should be considered in cases of abortion.

Prevention and Control Biosecurity and vaccination are the best ways to prevent BVDV and should be integrated into the herd health program. Vaccine preparations for BVDV are modified live (MLV) or inactivated virus. Each has advantages and disadvantages. The former induces rapid immunity (within 1 week) after a single dose, provides longer duration of immunity against several strains, and induces serum-neutralizing antibodies. However, MLV vaccines are not recommended for use in pregnant cattle, may induce mucosal disease, and may be immunosuppressive at the time of vaccination. Inactivated vaccines require booster doses after the initial immunization and do not induce cell-mediated immunity. Passive immunity may protect most calves up to 6–8 months of age. Subsequent vaccination with MLV may provide lifelong immunity but this is not guaranteed. Annual boosters are recommended to protect against vaccine breaks.

The virus persists in the environment for 2 weeks, and is susceptible to the disinfectants chlorhexidine, hypochlorite, iodophors, and aldehydes. Isolation and testing of new additions to the herd is critical, as is testing and culling PI cattle.

Treatment No specific treatment is available. Supportive care and treatment with antibiotics to prevent secondary infection are recommended.

v. CAE VIRUS

Etiology CAEV occurs worldwide with a high prevalence in the United States. CAE is considered the most important viral diseases of goats. The CAEV is in the genus *Lentivirus* of the family *Retroviridae*. It causes chronic arthritis and mastitis in adults and encephalitis in young. CAEV is in the same viral genus as the ovine progressive pneumonia virus (OPPV).

Clinical Signs and Diagnosis The most common presentation in goats is an insidious, progressive arthritis in animals 6 months of age and older. Animals become stiff, have difficulty getting up, and may be clinically lame in one or both forelimbs. Carpal joints are so swollen and painful that the animal prefers to eat, drink, and walk on its 'knees.' In dairy goats, milk production decreases and udders may become firmer. This retrovirus also causes neurological clinical signs in kids 2–6 months old. Kids may be bright and alert, afebrile, and able to eat normally even when recumbent. Some kids may initially show unilateral weakness in a rear limb which progresses to hemiplegia or tetraplegia. Mild to severe lower motor neuron deficits may be noted, but spinal reflexes are intact. Clinical signs may also include head tilt, blindness, ataxia and facial nerve paralysis.

Older animals in the group may experience interstitial pneumonia or chronic arthritis. The pneumonia is similar to the pneumonia in sheep caused by OPPV. The course of disease is gradual but progressive, and animals will eventually lose weight and have respiratory distress. Some animals in a herd may not develop any clinical signs.

Diagnosis is based on clinical signs, *post mortem* lesions, and positive serology for viral antibodies to CAEV. An AGID test identifies antibodies to the virus and is used for diagnosis. Kids acquire an anti-CAEV antibody in colostrum and this passive immunity may be interpreted as indicative of infection with the virus. The antibody does not prevent viral transmission.

Epizootiology and Transmission The virus is prevalent in most industrialized countries. The most common means of transmission is oral. Adults transfer virus to kids in colostrum and milk in spite of the presence of anti-CAEV antibody in the colostrum. Transmission may occur among adult goats by contact. Intrauterine transmission is believed to be rare.

Necropsy Findings Necropsy and histopathology reveal a striking synovial hyperplasia associated with the joints with infiltrates of lymphocytes, macrophages, and plasma cells. Other histologic lesions include demyelination in the brain and spinal cord with multifocal invasion of lymphocytes, macrophages, and plasma cells. Lung pathology is characteristic. In severe cases of mastitis, the udder may appear to be composed entirely of lymphoid tissue.

Differential Diagnoses The differential diagnosis for the neurologic form of CAEV should include copper deficiency, enzootic pneumonia, white muscle disease, rabies, listeriosis, thiamine deficiency, and spinal cord disease or injury. The differential diagnosis for CAEV arthritis and pneumonia should include *Chlamydophila* and *Mycoplasma*.

Prevention and Control Herds can be screened for CAE by testing serologically using AGID, ELISA, immunoprecipitation, or PCR. Since CAE is highly prevalent in the United States and since seronegative animals can shed organisms in the milk, retesting herds at least annually may be necessary. Control measures include test and culling, prevention of milk transmission, and isolation of affected animals. Parturition must be monitored and kids must be removed immediately and fed heat-treated colostrum (56°C for 1 h). CAEV-negative goats should be separated from -positive goats.

Treatment There is no treatment for CAEV.

vi. INFECTIOUS BOVINE RHINOTRACHEITIS VIRUS (IBRV) (INFECTIOUS PUSTULAR VULVOVAGINITIS (IBR-IPV), BOVINE HERPESVIRUS I)

Etiology The infectious bovine rhinotracheitis virus (IBPR) causes or contributes to several bovine syndromes including respiratory and reproductive tract diseases. It is one of the primary pathogens in the BRDC.

Clinical Signs and Diagnosis Diseases caused by the virus include conjunctivitis, rhinotracheitis, pustular vulvovaginitis, balanoposthitis, abortion, encephalomyelitis, and mastitis. The respiratory form is known as IBR or 'red nose.' Clinical signs may range from mild to severe with severity associated with the presence of additional respiratory viral infections or secondary bacterial infections. The mortality rate in more mature cattle is low, however, unless there is secondary bacterial pneumonia. Fever, anorexia, restlessness, hyperemia of the muzzle and nares, gray pustules on the muzzle (that later form plaques), nasal discharge progressing from serous to mucopurulent, hyperpnea, coughing, salivation, conjunctivitis with excessive epiphora, and decreased production in dairy animals are typical signs. Recovery generally occurs 4–5 days after the onset of clinical signs as long as there is no complication with bacterial pneumonia. Neonatal calves may develop respiratory as well as general systemic disease. Young calves are most susceptible to the encephalitic form; signs include dull attitude, head pressing, vocalizations, nystagmus, head tilt, blindness, convulsions, and coma. This form is usually fatal within 5 days. Abortion may occur simultaneously with as a sequel to the conjunctival or respiratory tract diseases regardless of the severity of the disease in the dam. Abortions are usually seen in the second half of pregnancy, but early embryonic death is possible. Infectious pustular vulvovaginitis (IPV) is most commonly seen in dairy cows; signs include fever, depression, anorexia, vulvar labia swelling, vulvar discharge, and reddened vaginal mucosa due to pustule development. If uncomplicated, the infection lasts about 4–5 days, and lesions heal in 2 weeks. Younger infected bulls may develop balanoposthitis with edema, swelling, and pain such that the animals will not service cows.

Diagnosis is based on clinical signs, virus isolation, or paired serum samples. Diagnosis can be made from aborted fetal tissues by virus isolation or fluorescent antibody staining.

Epizootiology and Transmission IBRV is widely distributed throughout the world, and adult animals are reservoirs of infection. Transmission is primarily by nasal secretions during and after clinical signs of disease.

Necropsy Findings Fibrinonecrotic rhinotracheitis is considered pathognomonic for IBRV respiratory tract infections. When there are secondary bacterial infections, such as *Pasteurella/Mannheimia* bronchopneumonia, findings will include congested tracheal mucosa and petechial and ecchymotic hemorrhages in that tissue. Lesions from the encephalitic form include lymphocytic meningoencephalitis, and will be found throughout the gray matter (neuronal degeneration, perivascular cuffing) and white matter (myelitis, demyelination). In younger animals, erosions and ulcers are coated with debris and may be found in the nose, esophagus, and forestomachs. White foci may be found in the liver, kidney, spleen, and lymph nodes. In the aborted fetus, pale, focal, necrotic lesions in all tissues may be found but are especially prevalent in the liver.

Differential Diagnoses The conjunctivitis of IBR may initially be mistaken for that of a *Moraxella bovis* (Pinkeye) infection; the IBR will be peripheral and there will not be corneal ulceration.

Prevention and Control Vaccination options include inactivated, attenuated, modified live, and genetically altered temperature-sensitive intranasal (IN) and parenteral preparations. Some are in combination with Parainfluenza Virus-3 (PI-3). The MLV preparations are administered intranasally; these are advantageous in calves for inducing mucosal immunity even when serologic passive immunity is already present and adequate. Parenteral MLV may cause abortion in pregnant cattle. Some newer vaccines, with gene deletion, allow for serologic differentiation between antibody responses from infection or immunization. Bulls and breeding and

replacement heifers should be immunized when 6–8 months old, prior to breeding and annually afterwards.

Treatment Uncomplicated mild infections will resolve over a few weeks; palliative treatments, such as cleaning ocular discharges and supplying softened food are helpful in recovery. Antibiotics are usually administered because of the high likelihood of secondary bacterial pneumonia. Treatment of encephalitic animals is unrewarding.

vii. PARAINFLUENZA-3 (PI-3)

Etiology Bovine parainfluenza 3 (BPI 3) is an RNA virus of the family *Paramyxoviridae* that causes mild respiratory disease of ruminants when it is the sole pathogen. Viral infection often predisposes the respiratory system to severe disease associated with concurrent viral or bacterial pathogens. Serotypes seen in the smaller ruminants are distinct from those isolated from cattle.

Clinical Signs Uncomplicated viral infections ranging from asymptomatic to mild signs of upper respiratory tract disease are almost never fatal. Clinical signs include ocular and nasal discharges, cough, fever, and increased respiratory rate and breath sounds. In pregnant animals exposure to BPI-3 can result in abortions. Clinical signs become apparent or more severe when additional viral pathogens, such as BVDV, or a secondary bacterial infection, such as *Mannheimia haemolytica*, are involved.

Diagnosis Viral isolation, direct IFA from nasal swabs, or paired serum samples can be useful.

Epizootiology and Transmission The virus is considered ubiquitous in cattle and a common infection in sheep. Presently it is assumed that the virus is widespread in goats but firm evidence is lacking.

Necropsy Findings For an infection of PI-3 only, findings will be negligible. Some congestion of respiratory mucosa, swelling of respiratory tract-associated lymph nodes, and mild pneumonitis may be noted grossly and histologically.

Differential Diagnoses Differentials, particularly in cattle, include infections with other respiratory tract viruses of ruminants: IBRV, BVDV, and BRSV.

Prevention and Control Immunization, management, and nutrition are important for this respiratory pathogen. In cattle, modified live vaccines for parenteral or IN administration are available. The IN vaccine immunizes in the presence of passively acquired antibodies, provides immunity within 3 days of administration, and stimulates the production of interferon. Booster vaccinations are recommended for all preparations within 2–6 months after the initial immunization. All presently marketed vaccine products come in combination with other bovine respiratory viruses (usually IBR). There is no approved PI-3 vaccine for sheep and goats. The use of the cattle formulation has been used.

Treatment Uncomplicated disease is not treated.

viii. RESPIRATORY SYNCYTIAL VIRUSES OF RUMINANTS (RSV)

Etiology The respiratory syncytial viruses are in the genus *Pneumovirus* in the *Paramyxoviridae* family and are common causes of severe disease in ruminants, especially calves and yearling cattle. Two serotypes of the BRSV have been described for cattle; these may be similar or identical to the virus seen in sheep and goats.

Clinical Findings and Diagnosis Infections may be subclinical or may develop into severe illness. Severe respiratory disease occurs upon initial exposure to the virus and subsequent exposures tend to result in mild to subclinical disease. Clinical signs include high fever, hyperpnea, spontaneous or easily induced cough, nasal discharge, and conjunctivitis. Interstitial pneumonia usually develops and harsh respiratory sounds are evident on auscultation. Open-mouthed breathing may be present in later stages of the disease. Emphysema of the dorsal subcutis from ruptured bullae is characteristic when present. Development of emphysema indicates a poor prognosis and death may occur in the severe cases of the viral infection. Secondary bacterial pneumonia, especially with *Mannheimia haemolytica*, with morbidity and mortality, are also common sequelae. Abortions have been associated with BRSV outbreaks.

Diagnosis is based on virus isolation and serology (acute and convalescent). Nasal swabs for virus isolation should be taken when animals have fevers and before onset of respiratory disease.

Epizootiology and Transmission These viruses are considered ubiquitous in domestic cattle and are transmitted by aerosols.

Necropsy Findings Gross lesions include consolidation of anteroventral lung lobes. Edema and emphysema are present. As the name indicates, syncytia, that may have small eosinophilic intracytoplasmic and rarely intranuclear inclusions, form in areas of the lungs infected with the virus. Necrotizing bronchiolitis, bronchiolitis obliterans, and hyaline membrane formation will be evident microscopically.

Differential Diagnoses Differentials should include other ruminant respiratory tract viruses such as BPI3, BVDV and bovine herpesvirus 1.

Prevention and Control Routine vaccination should be part of the standard health program. Passive immunity from colostrum does not appear to prevent BRSV infection, but does reduce the severity of the disease. The virus is easily inactivated in the environment.

Treatment Recovery can be spontaneous, however, antibiotics and supportive therapy are useful to prevent or control secondary bacterial pneumonia. In severe cases, antihistamines and corticosteroids may also be necessary.

ix. BORDER DISEASE (HAIRY SHAKER DISEASE)

Etiology Border disease, also known as hairy shaker disease, is a disease of sheep caused by a virus closely related to BVDV, a *Pestivirus* of the *Togaviridae* family. Goats are also affected.

Clinical Signs and Diagnosis Border disease in ewes causes early embryonic death, abortion of macerated or mummified fetuses, or birth of lambs with developmental abnormalities. Lambs infected *in utero* may be born weak and exhibit a number of congenital defects such as tremor or hirsutism (darkly pigmented over the shoulders and head), hypothyroidism, joint abnormalities including arthrogryposis, and central nervous system defects. Infection produces similar clinical manifestations in goats except that hirsutism is not seen.

Diagnosis includes the typical signs described above, as well as serological evidence of viral infection. Virus isolation, ELISA, or PCR confirms the diagnosis.

Epizootiology and Transmission The virus is present worldwide and reports of disease are sporadic. Persistently infected animals shed virus in urine, feces, and saliva throughout their lives.

Necropsy Findings Lesions include placentitis, and characteristic joint and haircoat changes in the fetus.

Prevention and Control Congenitally affected lambs should be humanely euthanized as soon as possible. Animals new to the flock should be screened serologically. Cattle housed near sheep should be regularly vaccinated for BVDV. Because border disease viruses of sheep have been proven antigenically distinct from BVD of cattle, the BVD vaccines for cattle cannot be recommended for control of border disease in sheep (Merck Veterinary Manual Online, 2011).

Treatment There is no treatment other than supportive care for affected animals.

x. ORF VIRUS DISEASE (CONTAGIOUS ECTHYMA, CONTAGIOUS PUSTULAR DERMATITIS, SORE MOUTH)

Etiology Contagious ecthyma, also known as contagious pustular dermatitis, sore mouth, or orf, is an acute dermatitis of sheep and goats caused by a member of the *Parapoxvirus* genus. This disease occurs worldwide and is zoonotic. Naturally occurring disease has also been reported in other species such as musk ox and reindeer.

Clinical Signs and Diagnosis The disease is characterized by the presence of papules, vesicles or pustules and subsequently scabs of the skin of the face, genitals of both sexes, and coronary bands of the feet. Lesions develop most frequently at mucocutaneous junctions and are found most commonly at the comissures of the mouth. Orf is usually identified in animals less than a year of age. Younger lambs and kids will have difficulty nursing and become weak. Lesions may also develop on udders of nursing dams. Morbidity in a susceptible group of animals may exceed 90%. Mortality is low but the course of the disease may last up to 6 weeks.

Diagnosis is based on characteristic lesions. Disease is confirmed by virus isolation.

Epizootiology and Transmission All ages of sheep and goats are susceptible. Seasonal occurrences immediately after lambing and after entry into a feedlot are common because stress plays a role in susceptibility to this viral disease. The virus is extremely resistant to environmental conditions and can contaminate small ruminant facilities for many years.

Necropsy Findings Except in the case of debilitated lambs, this disease does not usually result in necropsy.

Differential Diagnoses Ulcerative dermatosis and bluetongue virus should be considered in both sheep and goats as differentials. Another important differential in goats is staphylococcal dermatitis.

Prevention and Control Individuals handling infected animals should be advised of precautions beforehand, wear gloves, and separate work clothing and other personal protective equipment. Clippers, ear tagging devices, and other similar equipment should always be cleaned and disinfected after each use. Vaccinating lambs and kids with commercial vaccine best prevents the disease. Animals that must be introduced to an infected environment should be vaccinated upon arrival. Precautions must be taken when vaccinating animals because the vaccine may induce orf in animal handlers. It is not recommended to vaccinate animals in flocks already free of the disease.

Treatment Affected animals should be isolated and provided supportive care. Young animals may require tube feeding because mouths are too sore to nurse.

Research Complications Carrier animals may be a factor in flock or herd outbreaks. Contagious ecthyma is a zoonotic disease, and human-to-human transmission can also occur. Lesions in humans are extremely painful and may last as long as 6 weeks.

xi. FOOT AND MOUTH DISEASE (AFTOSA, FMDV)

Etiology The FMDV is a picornavirus in the *Aphthovirus* genus. Although epidemics of the disease have occurred worldwide, North and Central America have been free of the virus since the mid-1950s. This is a reportable disease in the United States, and clinical signs are very similar to other vesicular diseases. Cattle are the most susceptible species with swine being important hosts and propagators of the disease. Disease can occur in sheep and is usually subclinical in goats.

Clinical Signs and Diagnosis In addition to vesicle formation around and in the mouth, hooves and teats, fever, anorexia, weakness, and salivation occur.

Diagnosis must be based on ELISA, virus neutralization, fluorescent antibody tests, and complement fixation. Samples of vesicular fluid or epithelium can be

sent to the national laboratory responsible for diagnosis of FMD.

Epizootiology and Transmission FMDV is the most highly infectious agent described to date. Domestic and wild ruminants and several other species, such as swine, rats, bears, and llamas are hosts. The United States, Canada, Japan, New Zealand, and Australia are FMD-free, but the disease is endemic in most of South America, parts of Europe, and throughout Asia and Africa. The virus is very contagious and is spread primarily by inhaled aerosols which can be carried over long distances (up to 70 miles) or by fomites, such as shoes, clothing and equipment.

Necropsy Findings Vesicles, erosions and ulcers are present in the oral cavity as well as on rumen pillars and mammary alveolar epithelium.

Differential Diagnoses Vesicular stomatitis is the principal differential. Other differentials include mucosal disease, contagious ecthyma (orf), bluetongue, malignant catarrhal fever, bovine papular stomatitis, bovine herpes mammillitis, and IBR virus infection.

Prevention and Control Movement of animals and animal products from endemic areas is regulated. Vaccination, quarantine and slaughter are practiced in outbreaks in endemic areas.

Treatment Any suspicion of FMD infection should trigger notification of regulatory authorities; infected animals will be destroyed in FMDV-free countries.

Research Complications Importation into the United States of animals or animal products from endemic areas is prohibited.

xii. MALIGNANT CATARRHAL FEVER

Etiology Malignant catarrhal fever (MCF) is a severe disease primarily of cattle caused by bovine herpesvirus 6. The agents of MCF are viruses in the subfamily Gammaherpesvirinae and genus *Macavirus*. Disease may occur sporadically or as outbreaks. The sheep-associated form is due to OvHV-2.

Clinical Signs and Diagnosis Signs range from subclinical to recrudescing latent infections to the lethal disease seen in susceptible species, such as cattle. Sudden death may also occur in cattle. Presentations of the disease may be categorized as alimentary, encephalitis, or skin forms; all three may occur in an animal. Corneal edema starting at the limbus and progressing centripetally is a nearly pathognomonic sign; photophobia, severe keratoconjunctivitis and ocular involvement may follow. Other signs include prolonged fever, oral mucosal erosions, salivation, lacrimation, ropey catarrhal nasal discharge, encephalitis, and pronounced lymphadenopathy. Cattle may also have severe diarrhea. Recovery is usually prolonged and some permanent debilitation may occur. The disease is fatal in severely affected individuals.

Diagnosis is based on history of exposure as well as clinical signs and characteristic lesions Serology, PCR-based assays, viral isolation and cell culture assays are also used.

Epizootiology and Transmission Most ruminant species are susceptible to MCF. Sheep are asymptomatic sources of infection for cattle, which are dead-end hosts. Cattle should not be mixed with sheep for this reason. Other ruminants, including goats, may harbor the virus. Infection is spread by aerosol, direct contact and fomites such as water troughs, placental tissues, contaminated fomites, birds, and caretakers. The incubation period may be up to 3 months.

Necropsy This disease is systemic and lesions can be found in any organ. Gross findings at necropsy include necrotic and ulcerated nasal and oral mucosa; thickened, edematous, ulcerated and hemorrhagic areas of the intestinal tract; swollen, friable and hemorrhagic lymph nodes and other lymphatic tissues; and erosion of affected mucosal surfaces.

Differential Diagnoses The differentials for this disease are BVDV and mucosal disease, IBR, bluetongue, vesicular stomatitis, and FMD.

Prevention and Control There is no vaccine available at this time. In North America, sheep, and cattle that have been either exposed or that have survived the disease are reservoirs for outbreaks in other cattle. The virus is very fragile outside of host's cells and will not survive in the environment for more than a few hours.

Treatment Prognosis is grave. There is no specific treatment for MCF; supportive treatment may improve recovery rates.

xiii. OVINE PROGRESSIVE PNEUMONIA (OPP, VISNA/MAEDI)

Etiology An RNA virus in the genus *Lentivirus* of the family Retroviridae causes ovine progressive pneumonia (OPP). The 'Maedi' refers to the progressive pneumonia presentation of the disease. The 'Visna' refers to the central nervous system disease which is reported predominantly in Iceland. Genetic susceptibility to OPP has been implicated (Heaton and Leymaster, 2012).

Clinical Signs and Diagnosis OPP is characterized by weakness, unthriftiness, weight loss, and pneumonia in adult sheep (Pepin *et al.*, 1998; de la Concha Bermejillo, 1997). Clinically, animals exhibit signs of progressive pulmonary disease after an extremely long incubation period of up to 2 years. Respiratory rate and dyspnea gradually increase as the disease progresses; animals progressively lose weight and become weak. Mastitis is a common clinical feature. Thoracic auscultation reveals consolidation of ventral lung lobes, and hematological findings indicate anemia and leukocytosis. Rare neurological signs include flexion of fetlock and pastern joints, tremors of facial muscles, progressive paresis and paralysis, and depression and prostration.

Death occurs in weeks to months; secondary bacterial pneumonia may contribute to the animal's death.

The disease can be serologically diagnosed with AGID tests, virus isolation, serum neutralization, complement fixation and ELISA tests. A quantitative PCR is also available.

Epizootiology and Transmission Prevalence in some states in the United States is estimated at 60–80% (Herrmann-Hoesing *et al.*, 2007). It is transmitted horizontally via inhalation of aerosolized virus particles and vertically between the infected dam and fetus. Transmission through the milk or colostrum is considered common (Knowles, 1997).

Necropsy Findings Lesions are observed in lungs, mammary glands, joints, and the brain. Pulmonary adhesions, ventral lung lobe consolidation and bronchial lymph node enlargement, mastitis and degenerative arthritis are visualized grossly. Meningeal edema, thickening of the choroid plexus and foci of leukoencephalomalacia are seen in the central nervous system.

Differential Diagnoses Differential diagnoses are pulmonary adenomatosis and mycoplasmosis.

Prevention and Control Isolating or removing infected animals can prevent the disease. Facilities and equipment should also be disinfected. Some states have initiated control programs.

Treatment Treatment is unsuccessful.

xiv. POXVIRUSES OF RUMINANTS

Ovine Viral Dermatosis This is a venereal disease of sheep caused by a parapoxvirus distinct from contagious ecthyma (orf). The disease resolves within two weeks in healthy animals but lesions are painful, and resemble those of *C. renale* posthitis/vulvovaginitis. Symptomatic treatment may be necessary in some cases. There is no vaccine. Animals should not be used for breeding while clinical signs are present.

Proliferative Stomatitis (Bovine Papular Stomatitis)

Etiology A parapoxvirus is the causative agent of bovine papular stomatitis. This virus is considered to be closely related to the parapoxvirus causing contagious ecthyma and pseudocowpox. It is also a zoonotic disease. The disease is not considered of major consequence but high morbidity may be seen in severe outbreaks. In addition, lesions are comparable in appearance to those seen with vesicular stomatitis, BVDV, and FMDV. The disease occurs worldwide.

Clinical Signs and Diagnosis Raised red papules or erosions and shallow ulcers on the muzzle, nose, oral mucosa (including the hard palate), esophagus and rumen of cattle from 1 month to 2 years old are the most common findings. Morbidity among herds may be 100% but mortalities are rare. The infection may also be asymptomatic. Diagnosis is based on clinical signs and viral isolation. Handlers may develop lesions on their hands at sites of contact with lesions of cattle.

Pseudocowpox (Milker's nodes, Paravaccinia)

Etiology Pseudocowpox is a worldwide cattle disease caused by a parapox virus related to the causative agents of bovine papular stomatitis and orf (see above). Lesions are confined to the teats. This is also a zoonotic disease.

Clinical Signs and Diagnosis Minor lesions are usually confined to the teats. Lesions start as small red papules that proceed quickly to small vesicles or pustules and to scabs. These are distinctive due to the ring or horseshoe shape of the scab; some lesions may persist for months causing the teats to have a rough appearance and feel. Removal of scabs is painful. The teat lesions may predispose to mastitis due to the cows' resistance to milking.

Differential Diagnoses Differentials include bovine herpes mammillitis and papillomatosis.

Prevention and Control The virus is spread by contaminated hands and equipment, therefore milking hygiene is crucial.

Treatment Lesions should be treated symptomatically, and affected animals milked last.

Research Complications Like other related poxviruses, this virus causes nodular lesions on humans.

xv. PULMONARY ADENOMATOSIS (JAAGSIEKTE SHEEP RETROVIRUS)

Etiology Pulmonary adenomatosis is a rare but progressive wasting disease of sheep with worldwide distribution. Pulmonary adenomatosis is caused by a retrovirus in the genus *Betaretrovirus* antigenically related to the Mason–Pfizer monkey virus and is reportable in some states. Typical clinical signs include progressive respiratory signs such as dyspnea, rapid respiration and wasting. The disease is diagnosed by chronic clinical signs, viral antigen RNA, IHC, immunoblot, and PCR on tissues.

Research Impact Pulmonary adenomatosis is a common model used for research of retrovirus development, pulmonary neoplasia, and transmissible pulmonary neoplastic diseases.

xvi. PAPILLOMATOSIS (WARTS, VERRUCAE)

Etiology Cutaneous papillomatosis is a very common disease in cattle but is much less common among sheep and goats. The disease is a viral-induced proliferation of the epithelium of the neck, face, back, and legs. These tumors are caused by a papilloma (DNA) virus in the family Papillomaviridae. Viruses are host specific and often body-site specific. In cattle, the site specificity of papilloma virus strains around the head and neck is particularly well recognized.

Clinical Signs and Diagnosis Papillomas may last for up to 12 months and are seen more frequently in younger animals. Lesions will have typical wart appearances and be single or multiple, small (1 mm) to very large (500 mm). The infections will generally be benign although when infections are severe, weight loss may occur. When warts occur on teats, secondary mastitis may develop. Prognosis in cattle is poor only when papillomatosis involves more than 20% of the body surface.

In sheep and goat, warts are the verrucous type. The disease is of little consequence unless warts develop in an area that causes discomfort or incapacitation such as between the digits, on the lips, or over the joints. Warts on goat udders tend to be persistent.

Diagnosis is made by observing the typical proliferative lesions.

Epizootiology and Transmission The virus is transmitted by direct and indirect (fomites) contact, entering through surface wounds and sites such as tattoos. DNA from papillomavirus has been found in blood, milk, urine, and other fluids obtained from infected animals. The incubation period ranges from 1 to 6 months. The disease is generally self-limiting.

Prevention and Control Commercial (available only for cattle) or autogenous vaccines must be used with a recognition that a host specificity of papillomavirus strains exists and that immunity from infection or vaccination is viral-type specific. Autogenous vaccines are generally considered more effective Virucidal products are recommended for disinfection of contaminated environments. Minimizing cutaneous injuries and sanitizing equipment (tattoo devices, dehorners, ear taggers, etc.) in a virucidal solution between uses are recommended preventative measures.

Treatment Warts will often spontaneously resolve as immunity develops. Warts can be amputated with scissors and autogenous vaccines can be made and administered to help prevent disease spread. Cryosurgery with liquid nitrogen or dry ice has also proven to be successful.

xvii. PSEUDORABIES (MAD ITCH, AUJESZKY'S DISEASE)

Etiology Pseudorabies is an acute encephalitic disease caused by a neurotropic member of the subfamily *Alphaherpesvirinae*, the Suid herpesvirus 1. One serotype is recognized but strain differences exist. The virus has worldwide distribution; it has been eradicated from domestic livestock in the United States but is prevalent in feral swine. It is a primarily a clinical disease of swine and cattle with less frequent reports in sheep and goats.

Clinical Signs and Diagnosis A range of clinical signs is seen during the rapid course of this usually fatal disease. At the site of virus inoculation or in other locations, abrasions, swelling, intense pruritus and alopecia are seen. Animals are hyperthermic and vocalize frantically. Other neurological signs range from hoof stamping, kicking at the pruritic area, salivation, tongue chewing, head pressing and circling, nystagmus and strabismus to paresthesia or hyperesthesia, ataxia, and conscious proprioceptive deficits. Animals may be fearful or depressed, or aggressive. Recumbency and coma precede death.

Diagnosis is by virus isolation and fluorescent antibody testing from nasal or pharyngeal secretions or *post mortem* tissues, and histological findings at necropsy.

Epizootiology and Transmission Swine are the primary hosts for pseudorabies virus, but they are usually asymptomatic and serve as reservoirs for the virus. Other animals are dead-end hosts. The unprotected virus will survive only a few weeks in the environment but may remain viable in meat (including carcasses) for weeks to months. Transmission is by direct contact or fomites, fecal–oral, or aerosol. Pets or wildlife are a risk as they can carry the organism between farms, although they live only 2–3 days after becoming infected. Transmission can also be by inadvertent exposure (e.g., contaminated syringes) of ruminants to the modified live vaccines developed for use in swine.

Necropsy Findings There is no pathognomonic gross lesion. Definitive histologic findings include severe, focal, nonsuppurative encephalitis and myelitis.

Differential Diagnoses Differentials for the neurologic signs of pseudorabies infection include rabies, polioencephalomalacia, salt poisoning, meningitis, lead poisoning, hypomagnesemia, and enterotoxemia. Those for the intense pruritus include psoroptic mange and scrapie in sheep, sarcoptic mange, and pediculosis.

Prevention and Control Pseudorabies is a reportable disease in the United States where a nationwide eradication program exists.

Treatment There is no treatment and most affected animals die.

Research Complications Any suspicion of pseudorabies virus infection should be promptly reported to animal health authorities.

xviii. RABIES (HYDROPHOBIA)

Etiology Rabies is a sporadic but highly fatal acute viral disease affecting the central nervous system. The rabies virus is a neurotropic RNA virus of the genus *Lyssavirus* and the family Rhabdoviridae that can affect any mammal. Sheep, goats, and cattle are susceptible. The zoonotic potential of this virus must be kept in mind at all times when handling moribund animals with neurological signs characteristic of the disease. Rabies is endemic in many areas of the world and within areas of the Unites States. This is a reportable disease in North America.

Clinical Findings and Diagnosis The most reliable signs in all species are acute behavioral changes and

unexplained progressive paralysis. Animals generally progress through three phases: prodromal, excitatory, and paralytic. Many signs during these stages are nonspecific. During the short prodromal phase, animals are hyperthermic and apprehensive. In the excitatory phase, they refuse to eat and drink, are active and aggressive. Repeated vocalizations, tenesmus, sexual excitement, and salivation occur during this phase. The final paralytic stage, with recumbency and death, occurs over several hours to days. The clinical course is usually 1–4 days.

Diagnosis is based on clinical signs with a progressive and fatal course. Confirmation presently is made with the fluorescent antibody technique on brain tissue.

Epizootiology and Transmission The rabies virus is transmitted via a bite-wound inflicted by a rabid animal. Cats, dogs, raccoons, skunks, foxes, wild canids, and bats are the common disease vectors in North America.

Necropsy Findings Few lesions are seen at necropsy. Negri bodies in the cytoplasm of neurons of the hippocampus and in Purkinje cells are pathognomonic histologic findings.

Differential Diagnoses Rabies should be included on the differential list when clinical signs of neurologic disease are evident. Other differentials for ruminants include herpesvirus encephalitis, thromboembolic meningoencephalitis, nervous ketosis, grass tetany, and nervous cocciodiosis.

Control Vaccines approved for use cattle and sheep are commercially available and contain inactivated virus; no vaccine is currently approved for goats in the United States. Ruminants in endemic areas, such as the East Coast of the United States, should be routinely vaccinated. Monitoring for and exclusion of wildlife from large animal facilities are worthwhile preventative measures.

Research Complications Personal protective equipment must be worn by individuals handling animals manifesting neurological disease signs, including gloves, face mask, and eye shields.

xix. SCHMALLENBERG VIRUS

Etiology Schmallenberg virus is an orthobunyavirus named for the city in Germany where it was discovered in late 2011. Sheep, goats, and cattle are susceptible. It is thought to be found only in Europe at present.

Clinical Findings and Diagnosis Affected animals including sheep, cattle, and goats, present with fever, diarrhea, and decreased milk production in milking animals. Still births are seen in all three species, as well as congenital malformations. No illness has been seen in the dams prior to the reproductive effects. Congenital malformations include scoliosis, hydrocephalus, arthrogryposis, and hypoplasia of the cerebellum. Diagnosis can be accomplished through RT-PCR via a blood sample or brain and spleen tissue.

Differential Diagnoses Clinical signs and reproductive issues mimic several other pathogens described in this chapter.

Prevention and Control The virus is thought to be transmitted by midges therefore is primarily seen in warm weather months. Some early information on affected herds has shown some tendency towards naturally acquired immunity. Currently, there are import bans in different countries around Europe and the world involving areas where this virus has been diagnosed (Garrigliany *et al*., 2012).

xx. TRANSMISSIBLE SPONGIFORM ENCEPHALOPATHIES

Bovine Spongiform Ecephalopathie (BSE or 'Mad Cow Disease')

Subsequent to the BSE outbreak in Great Britain in the 1980s, the USDA restricted importation of live cattle and certain ruminant products from countries affected with BSE. The USDA also has an ongoing BSE surveillance program, designed to detect the disease at the level of 1 case per 1,000,000 cattle. Because the probability of encountering BSE in the research environment is very low, readers are directed to the USDA/APHIS website for current information. Also, investigators should be cognizant of measures taken by suppliers of biological reagents to mitigate the risk of contamination with the BSE agent.

Scrapie

Etiology Scrapie is the TSE of sheep and goats, and like BSE is a reportable disease. It is enzootic in many countries and is much more common in sheep than goats.

Clinical Signs and Diagnosis During early clinical stages, animals are excitable and hard to control. Tremors of head and neck muscles, as well as uncoordinated movements and unusual 'bunny hopping' gaits are observed. Lip smacking may also be seen. Animals experience severe pruritus and will self-mutilate while rubbing on fences, trees, and other objects. Blindness and abortion may also be seen. Morbidity may reach 50% within flock. Most animals die within a 4- to 6-week period, although some animals may survive 6 months. In goats, pruritus is generally less severe. Other clinical signs noted in goats include listlessness, stiffness or restlessness, or behavioral changes such as irritability, hunched posture, twitching, and erect tail and ears. As with sheep, the disease gradually progresses to anorexia, debilitation, and death.

Diagnosis is based on clinical signs and histopathological lesions. A newer diagnostic test in live animals is based on a biopsy from the third eyelid (nictitating membrane) by regulatory veterinarians. Blood tests are available for genetic susceptibility.

Epizootiology and Transmission The Suffolk breed tends to be especially susceptible, although scrapie has also been reported in several other breeds. Genomic

research indicates there are three nonsynonymous genetic polymorphisms in the *PRP* gene governing susceptibility at codons 136, 154, and 171. VRQ/VRQ animals are most susceptible; ARR/ARR animals are resistant. Scrapie is transmitted horizontally to neonates or juveniles by direct or indirect contact; nasal secretions or placentas serve as sources of the infectious agent. Transplacental transmission is considered unlikely. Because of the long incubation period (from 2 to 5 years), only adult animals display signs of the disease. State and federal eradication programs exist. See *A Guide to the National Scrapie Eradication Program for Veterinarians* (2009) for additional information.

Necropsy Findings At necropsy, no gross lesion is observed. Histopathologically, neuronal cytoplasmic vacuolization, astrogliosis, and spongiform degeneration are visualized in the brainstem, spinal cord, and especially thalamus.

Differential Diagnoses In sheep and goats, depending on the speed of onset, differentials for the pruritus include ectoparasites, pseudorabies, and photosensitization.

Prevention and Control If diagnosed in a flock, quarantine and slaughter, followed by strict sanitation are required. The USDA is currently leading a National Scrapie Eradication Program. Scrapie-positive animals are identified, reported, and culled. Genetic selection for shipping, breeding and purchasing is then used to eradicate the disease. Scrapie-free flocks are given identification tags and sheep purchases should be done after confirming the status of a flock (USDA/APHIS, 2012).

Treatment No vaccine or treatment is available.

Research Complications As noted, this is a reportable disease. Stringent regulations exist in the United States regarding importation of small ruminants from scrapie-infected countries.

xxi. VESICULAR STOMATITIS VIRUS

Etiology Vesicular stomatitis (VS) is caused by the vesicular stomatitis virus (VSV), a member of the family Rhabdoviridae. It is a reportable disease in the United States and is zoonotic. The New Jersey and Indiana strains cause sporadic disease in cattle in the United States.

Clinical Signs and Diagnosis Adult cattle are most likely to develop VS. Fever and development of vesicles on the oral mucous membranes are the initial clinical signs. Lesions on the teats and interdigital spaces also develop. The vesicles progress quickly to ulcers and erosions. The animal's tongue may be severely involved. Anorexia and salivation are common. Weight loss and decreased milk production are noticeable. Morbidity will be high in an outbreak but mortality will be low to nonexistent.

Due to its similarity to FMDV, regulatory agencies should be involved in diagnostic work-up. Diagnosis is based on analysis of fluid, serum, or membranes associated with the vesicles. Virus isolation, ELISA, CELISA, CF, serum neutralization, and RT-PCR are used for diagnosis.

Epizootiology and Transmission This disease occurs in several other mammalian species, including swine, horses, and wild ruminants. VSV survives well in different environmental conditions, including in soil, extremes of pH, and low temperatures. Equipment, such as milking machines or human hands can serve as mechanical vectors. Transmission may also be from contaminated water, feed, and insects. Incubation period is 2–8 days. It is believed that carrier animals do not occur in this disease.

Necropsy It is rare for animals to be necropsied as the result of this disease.

Differential Diagnoses VSV lesions are identical to FMDV lesions. Other differentials in cattle include bovine viral diarrhea, malignant catarrhal fever, contagious ecthyma, photosensitization, trauma, and caustic agents.

Prevention and Control Quarantine and restrictions on shipping infected animals or animals from the premises housing affected animals are required in an outbreak. Vaccines are available for use in outbreaks. Phenolics, quaternaries, and halogens are effective for inactivating and disinfecting equipment and facilities.

Treatment Affected animals should be segregated from the rest of the herd, provided with separate water and softened feed. Topical or systemic antibiotics control secondary bacterial infections. Cases of mastitis secondary to teat lesions must be treated as necessary.

Research Complications Animals developing vesicular lesions must be reported promptly to eliminate the possibility of FMDV. VSV causes a flu-like illness in humans.

xxii. VIRAL DIARRHEA DISEASES

Rotavirus Rotavirus, a virus in the family *Reoviridae*, induces an acute, transient diarrhea in calves and lambs within the first few weeks of life. The disease is characterized by yellow, semifluid to watery malabsorptive diarrhea occurring 1–4 days after infection. The disease can progress to dehydration, anorexia and weight loss, acidosis, depression, and occasionally death. Transmission is fecal–oral. Virus may remain in the environment for several months. The disease is diagnosed by virus isolation, electron microscopy of feces, fecal fluorescent antibody, fecal ELISA tests (marketed tests generally detect group A rotavirus), and by fecal latex agglutination tests. Rotavirus diarrhea is treated by supportive therapy, including maintaining hydration, electrolyte, and acid–base balance. A rotavirus vaccine is available for cattle; because of cross-species immunity,

oral administration of high-quality bovine colostrum from vaccinated cows to lambs at risk may be helpful (Youngquist and Threlfall, 2007).

Coronavirus Bovine coronavirus, of the family *Coronaviridae*, produces a more severe, long-lasting disease compared to rotavirus. Clinical signs in lambs and calves are similar to above, although the incubation period tends to be shorter (20–36 h). In addition, mild respiratory disease may be noted (Janke, 1989). Coronavirus infections may be complicated by parasite infestation (e.g., *Cryptosporidia, Eimeria*) or bacterial infections (e.g., *E. coli, Salmonella*). Treatment is aimed at correcting dehydration, electrolyte imbalances, and acidosis. Strict hygiene and effective passive transfer by developing good colostrum-management protocols are critical. Bovine vaccines are available both for delivery to pre-partum dams and for the neonate.

Rotaviruses, coronavirus, and adenoviruses affect neonatal goats; however, little has been documented on the pathology and significance of these agents in this age group. Unlike calves, it appears that bacteria play a more important role in neonatal kid diarrheal diseases than in neonatal calf diarrheas. Parvovirus and BVDV also may cause diarrhea in neonatal calves.

Winter Dysentery Winter dysentery is an acute epizootic diarrheal disease of housed adult cattle in winter months although it has been reported in 4-month-old calves. The etiology has not yet been defined but coronavirus-like viral particles have been isolated from cattle feces, either the same as or similar to the coronavirus of calf diarrhea. Outbreaks typically last a few weeks, and first lactation or younger cattle are affected first with waves of illness moving through a herd. Individual cows are ill for only a few days. The incubation period is estimated at 2–8 days. Clinical signs include explosive diarrhea, anorexia, depression, and a profound decrease in production. The diarrhea has a distinctive musty, sweet odor, and is light brown and bubbly, but some blood streaks or clots may be mixed in with the feces. Animals will become dehydrated quickly but are thirsty. Respiratory signs such as nasolacrimal discharges and coughing may develop. Recovery is generally spontaneous within a few days. Mortalities are rare. Diagnosis is based on characteristic patterns of clinical signs, and elimination of diarrheas caused by parasites such as coccidia, bacterial organisms such as *Salmonella* or *Mycobacterium paratuberculosis*, and viruses such as BVDV. Pathology is present in the colonic mucosa and necrosis is present in the crypts.

b. Chlamydophilal Diseases

i. ENZOOTIC ABORTION OF EWES (EAE), CHLAMYDOPHILAL ABORTION

Etiology The etiologic agent of Enzootic Abortion of Ewes is now known *as Chlamydophila abortus (Chlamydophila psittaci serotype 1)*, a nonmotile, obligate intracytoplasmic, gram-negative bacterium.

Clinical Signs Enzootic abortion in sheep and goats is a contagious disease characterized by hyperthermia and late abortion, or birth of stillborn or weak lambs or kids (Rodolakis *et al.*, 1998). The only presenting clinical sign may be serosanguineous vulvar discharges. Other animals may present with arthritis or pneumonia. Infection of animals prior to 120 days of gestation results in abortion, stillbirths, or birth of weak lambs. Infection after 120 days results in potentially normal births, but the dams or offspring may remain latently infected. Ewes or does generally abort only once. Recovered animals will be immune to future infections.

Epizootiology and Transmission The disease is transmitted by direct contact with infectious secretions such as placental, fetal, and uterine fluids; or by indirect contact with contaminated feed and water.

Necropsy Placental lesions include intercotyledonary plaques and necrosis and cotyledonary hemorrhages. Histopathological evidence of leukocytic infiltration, edema, and necrosis is found throughout the placentome. Fetal lesions include giant cell accumulation in mesenteric lymph nodes and lymphohistiocytic proliferations around the blood vessels within the liver.

Diagnosis Diagnosis is based on clinical signs and immunofluorescence, ELISA, cell culture isolation, and RT-PCR methods (Stuen and Longbottom, 2011) Impression smears in placental tissues stained with Giemsa, Gimenez, or modified Ziehl–Neelsen can provide preliminary indications of the causative agent.

Differential Diagnoses Q fever will be the major differential for late-term abortion and necrotizing placentitis. *Campylobacter* and *Toxoplasma* should also be considered for late-term abortion.

Treatment Animals may respond to treatment with oxytetracycline. Vaccination will prevent abortions but not eliminate infections. The vaccine should be administered before breeding and annually to at least the young females entering the breeding herd or flock.

Research Complications In addition to losses or compromise of research animals, pregnant women should not handle aborted tissues.

ii. CHLAMYDOPHILAL POLYARTHRITIS OF SHEEP

Etiology *Chlamydophila pecorum* is a nonmotile, obligate intracellular, gram-negative bacterium causing acute polyarthritis and conjunctivitis in growing and nursing lambs.

Clinical Signs Clinically, animals will appear lame on one or all legs and in major joints including the scapulohumeral, humeroradioulnar, coxofemoral, femorotibial, and tibiotarsal joints. Lambs may be anorexic

and febrile. Animals frequently also exhibit concurrent conjunctivitis. The disease usually resolves in approximately four weeks. Joint inflammation usually resolves without chronic articular changes.

Epizootiology and Transmission The disease is transmitted to susceptible animals by direct contact as well as by contaminated feed and water. The organism penetrates the gastrointestinal tract and migrates to joints and synovial membranes as well as the conjunctiva.

Necropsy Findings Lesions are found in joints, tendon sheaths, conjunctiva, and lungs. Pathological sites will be edematous and hyperemic with fibrinous exudates, but without articular changes. Lesions will be infiltrated with mononuclear cells. Lung lesions include atelectasis and alveolar inspissation.

Diagnosis Diagnosis is based on clinical signs. Synovial taps and subsequent smears may allow the identification of chlamydophilal inclusion bodies.

Treatment Animals respond to treatment with parenteral oxytetracycline.

iii. CHLAMYDOPHILAL CONJUNCTIVITIS (INFECTIOUS KERATOCONJUNCTIVITIS; 'PINKEYE')

Etiology *Chlamydophila psittaci* and *Chlamydophila pecorum* are the most common causes of infectious keratoconjunctivitis in sheep. *Chlamydophila* and *Mycoplasma* are considered to be the most common causes of this disease in goats.

Clinical Signs Infectious keratoconjunctivitis is an acute, contagious disease characterized in earlier stages by photophobia, conjunctival hyperemia, epiphora, and edema, and in later stages by ulceration and opacity. Perforation may result from the ulceration. In less severe cases, corneal healing associated with fibrosis and neovascularization occurs in 3–4 days. Lymphoid tissues associated with the conjunctiva and nictitans membrane may enlarge and prolapse the eyelids. Morbidity may reach 80–90%. Bilateral and symmetrical infections characterize most outbreaks. Relapses may occur. Other concurrent systemic infections may be seen such as polyarthritis or abortion in sheep, and polyarthritis, mastitis, and uterine infections in goats.

Epizootiology and Transmission Direct contact as well as mechanical vectors such as flies easily spread the organism.

Necropsy This disease does not usually result in mortality.

Differential Diagnoses Nonchlamydophilal keratoconjunctivitis also occurs in sheep and goats. The primary agents involved include *Mycoplasma conjunctiva, Mycoplasma agalactiae* in goats, *Moraxella* (*Branhamella*, *Neisseria*) *ovis*, and *Colesiota conjunctivae* (a rickettsia-like organism). Other differentials include eyeworms, trauma, and foreign bodies such as windblown materials (pollen, dust) and poor-quality hay.

Prevention and Control Source of mechanical irritation should be minimized and shade provided. Quarantine of new animals and treatment before introduction into the flock or herd are important measures.

Treatment Infections are self-limiting in 2–3 weeks without treatment. Treatment consists of topical application of tetracycline ophthalmic ointments. Systemic or oral oxytetracycline treatments have been used with the topical treatment. Atropine may be added to the treatment regimen when uveitis is present.

3. Parasitic

a. Protozoan

i. ANAPLASMA

Etiology Anaplasmosis is a transmissible hemolytic disease of cattle caused by the protozoan *Anaplasma marginale*. In sheep and goats, the disease is caused by *A. ovis* and is a relatively rare cause of hemolytic disease. This summary addresses the disease in cattle with limited reference to *A. ovis* infections, but there are many similarities to the disease in cattle.

Clinical Signs and Diagnosis Acute anemia is the predominant sign in anaplasmosis, and fever coincides with parasitemia. Weakness, pallor, lethargy, dehydration, and anorexia are the result of the anemia. The incubation stage may be long, 3–8 weeks, and is characterized by a rise in body temperature as the infection moves to the next stage. Most clinical signs occur during the 4- to 9-day developmental stage, with hemolytic anemia being common. Death is most likely to occur at this stage or at the beginning of the convalescent stage. Death may also occur from anoxia due to the animal's inability to handle any exertion or stress, especially if treatment is initiated when severe anemia exists. Reticulocytosis characterizes the convalescent stage which may continue for many weeks. Morbidity is high and mortality low. The carrier stage is defined as the time in the convalescent stage when the animal host becomes a reservoir of the disease and parasitemia is not discernible.

Diagnosis is made by clinical and necropsy findings. Common serologic tests include the complement fixation and rapid card tests. These become positive after the incubation phase. Staining of thin blood smears with Wright's or Giemsa stains allows detection of basophilic, spherical *A. marginale* bodies near the red blood cell (RBC) peripheries. A negative finding should not eliminate the pathogen from consideration.

Epizootiology and Transmission The disease is common in cattle in the southern and western United States and other tropical and subtropical regions. *Anaplasma* organisms are spread biologically or mechanically. Mechanical transmission occurs when infected

RBC are passed from one host to another on the mouth parts of seasonal biting flies, mosquitos, or instruments such as dehorners or hypodermic needles. Biological transmission occurs when the organism is passed by carrier *Dermacentor andersoni* and *D. occidentalis* ticks. Recovered animals serve as disease reservoirs.

Necropsy Pale tissues and watery, thin blood are typical findings. Splenomegaly, hepatomegaly, and gall bladder distension are common findings.

Pathogenesis The parasites infect the host's RBCs, and acute hemolysis occurs during the parasites' developmental stage.

Differential Diagnosis The clinical disease closely resembles the protozoal disease babesiosis.

Prevention and Control Offspring of immune carriers resist infection up to 6 months of age due to passive immunity. Vector control and attention to hygiene are essential, such as between-animal disinfection of equipment such as dehorners. Vaccination (killed whole organism) is not entirely effective as vaccinated animals can still become infected and become carriers. Vaccine should not be administered to pregnant cows due to the potential for neonatal isoerythrolysis. There is no *A. ovis* vaccine. Identifying carriers serologically and treating with tetracycline during and/or after vector seasons may be an option. Interstate movement of infected animals is regulated.

Treatment A single dose of long-acting tetracycline reduces the severity of the infection during the developmental stage. Other tetracycline treatment programs have been described to help control carriers.

ii. BABESIOSIS (RED WATER, TEXAS CATTLE FEVER, CATTLE TICK FEVER)

Etiology *Babesia bovis* and *Babesia bigeminia* are intraerythrocytic protozoans that cause subclinical infections or disease in cattle. Babesiosis is one of the most important arthropod-borne diseases of cattle and is very prevalent in tropical and subtropical areas worldwide. This disease is not seen in the smaller ruminants in the United States. See Center for Food Security and Public Health (2008) for more information on Babesiosis.

Clinical Signs and Diagnosis The more common presentation is liver and kidney failure due to hemolysis with icterus, hemoglobinuria, and fever. Acute encephalitis is a less common presentation and begins acutely with fever, ataxia, depression, deficits in conscious proprioception, mania and convulsions, and coma. The encephalitic form generally also has a poor prognosis. Sudden death may also occur.

Diagnosis Thin blood smears stained with Giemsa will show *Babesia* trophozoites at some stages of the disease. Complement fixation, immunofluorescent antibody and ELISA are the most favored of the available serologic tests.

Epizootiology and Transmission The primary vectors for Babesia are ticks of the *Boophilus* genus. In addition to domestic cattle, some wild ruminants such as white-tailed deer and American buffalo are also susceptible. *Bos indicus* breeds have resistance to the disease and the tick vectors. Stress can cause disease development.

Necropsy Findings Signs of acute hemolytic crisis are the most common findings and include hepatomegaly, splenomegaly, dark and distended gallbladder, pale tissues, thin blood, scattered hemorrhages, and petechiation. Animals dying after longer course of disease will be emaciated and icteric with thin blood, pale kidneys, and enlarged liver.

Differential Diagnoses In addition to anaplasmosis, leptospirosis, copper toxicity and bacillary hemoglobinuria are differentials for the hemolytic form of the disease. Several differentials in the United States for the encephalitic presentation include rabies, nervous system coccidiosis, polioencephalomalacia, lead poisoning, IBR, and salt poisoning.

Prevention and Control Control or eradication of ticks and cleaning of equipment to prevent mechanical transmission are important preventative measures. Vaccination approaches have been effective in South American and Australia but a commercial product is not available in the United States.

Treatment Supportive care is indicated including blood transfusions, fluids, and antibiotics. Medications such as diminazene diaceturate, diisethionate, and imidocarb dipropionte are most commonly used.

Research Complications Babesiosis is a reportable disease in the Unites States.

iii. COCCIDIOSIS

Etiology Coccidia are protozoal organisms of the phylum Apicomplexa, members of which are obligatory intracellular parasites. Coccidia spp. have a complex lifecycle in which sexual and asexual reproduction occurs in gastrointestinal enterocytes. Sheep, goats, and cattle are all affected by multiple species of the genus *Eimeria*, however, the species of parasite are host-specific as well as host-cell specific.

Clinical Signs and Diagnosis Coccidiosis is an important protozoal disease of young ruminants characterized primarily by hemorrhagic diarrhea. Diarrhea develops 10 days to 3 weeks after infection. Fecal staining of the tail and perineum will be present. Animals will frequently display tenesmus and rectal prolapses may develop. Anorexia, weight loss, dehydration, anemia, fever (infrequently), depression, and weakness may also be seen in all ruminants. The diarrhea is watery and malodorous and will contain variable amounts of blood and fibrinous, necrotic tissues. The intestinal hemorrhage may subsequently lead to anemia and hypoproteinemia.

Concurrent disease with other enteropathogens may also be part of the clinical picture.

The disease is usually diagnosed by history and clinical signs. Numerous oocysts will be observed in fresh fecal flotation (salt or sugar solution) samples as the diarrhea begins. The pre-patent period for *Eimeria* is from 2 to 3 weeks and usually coincides with the development of clinical signs.

Epizootiology and Transmission Subclinically infected adults are the reservoir for the parasites. The disease is transmitted to young animals via ingestion of sporulated oocysts; severity of the disease is correlated primarily with the number of ingested oocysts. Coccidial oocysts remain viable for long periods of time when in moist, shady conditions. Isolated outbreaks in adults may occur after stressful conditions such as transportation or diet changes.

Necropsy Necropsies provide information on specific locations and severity of lesions that correlate with the species involved. Ileitis, typhlitis, and colitis with associated necrosis and hemorrhage will be observed. Mucosal scrapings will frequently yield oocysts.

Differential Diagnoses These include the many enteropathogens associated with acute diarrhea in young ruminants: cryptosporidiosis, colibacillosis, salmonellosis, enterotoxemia, viral diarrheas, and other intestinal parasites such as helminths.

Prevention and Control Proper sanitation of maternity pens and young stock housing and minimizing overcrowding are essential. Coccidiostats added to the feed, water, or milk replacer are helpful in preventing the disease in areas of high exposure.

Treatment Affected animals should be isolated. Treatment should include provision of a dry, warm environment, fluids, electrolytes (orally or intravenously), antibiotics (to prevent bacterial invasion and septicemia), and administration of coccidiostats. Coccidiostats are preferred to coccidiocidals because the former allow immunity to develop. Sulfonamides and amprolium may be used to aid in the treatment of disease, as well as decoquinate, lasalocid and monensin. Labels should be checked for specific approval in a species or indications. Penmates of affected animals should be considered exposed and treated to control early stages of infection.

iv. CRYPTOSPORIDIOSIS

Etiology *Cryptosporidium* organisms are a very common cause of diarrhea in young ruminants. There are at least 16 species and more than 40 genotypes of species, some of which affect multiple host species. Cryptosporidiosis is a zoonotic disease.

Clinical Signs and Diagnosis Cryptosporidiosis is characterized by protracted, malabsorptive diarrhea and debilitation. The diarrhea may last only 6–10 days, or may be persistent and fatal. Infected animals will display tenesmus, anorexia and weight loss, dehydration, and depression. In relapsing cases, animals become cachectic. Overall, morbidity will be high, and mortality variable.

Mucosal scrapings or fixed stained tissue sections may be useful in diagnosis. The disease is also diagnosed by detecting the oocysts on fecal flotation, in iodine-stained feces, or periodic acid Schiff (PAS) or methenamine silver-stained tissues. *Cryptosporidium* also stains red on acid-fast stains such as Kinyoun or Ziehl–Neelsen. Fecal IFA techniques have also been described.

Epizootiology and Transmission Younger ruminants are commonly affected including lambs, kids between the ages of 5–10 days of age, and calves less than 30 days old. *Cryptosporidium* is transmitted via the fecal–oral route. The oocysts are shed sporulated and are immediately infective. Within 2–7 days of exposure, diarrhea and oocyst shedding occurs. The oocysts are extremely resistant to desiccation in the environment and may survive in the soil and manure for many months. Autoinfection within the lumen of the intestines may also occur and result in persistent infections. Cattle are frequently subclinical or asymptomatic carriers. All cattle should be assumed to be *Cryptosporidium* positive and appropriate precautions to prevent zoonotic spread should be instituted.

Necropsy Findings Gross lesions caused by *Cryptosporidium* are nonspecific. Animals will be emaciated. Moderate enteritis, hyperplasia of the crypt epithelial cells with villous atrophy as well as villous fusion, primarily in the lower small intestines, will be present. Organisms are located at the apical margin of the enterocytes in a characteristic intracellular, extracytoplasmic parasitophorous vacuole. Identification of organisms in tissue section is diagnostic.

Differential Diagnoses Other causes of diarrhea in younger ruminants include rota- and coronavirus, other enteric viral infections, enterotoxigenic *E. coli*, *Clostridia*, and other coccidial pathogens. These other agents may be contributing to illness in the affected animals and may complicate the diagnosis and treatment picture.

Prevention and Control Affected animals must be removed and isolated as soon as possible. Animal housing areas should be disinfected with undiluted commercial bleach or 5% ammonia. After cleaning, areas should be allowed to dry thoroughly, and remain unpopulated for a period of time. Use of powerwashers is not recommended, as this will facilitate spread of oocysts. Management and husbandry should be examined. Clinical cryptosporidiosis is often associated with failure of passive immune transfer or inadequate nutrition, so these factors should be scrutinized.

Treatment Halofuginone lactate has been approved in Europe for treatment of cryptosporidiosis in cattle. Nitazoxanide and paromomycin has been approved for

treatment of immunocompetent humans but are not approved for veterinary use. The disease is generally self-limiting so symptomatic, supportive therapy aimed at rehydrating, correcting electrolyte and acid–base balance, and providing energy is often effective.

Research Complications Cryptosporidiosis is a zoonotic disease. This disease is easily spread from calves to humans as the result of simply handling clothing soiled by calf diarrhea. The disease can be life threatening in immunocompromised individuals.

v. GIARDIASIS

Etiology *Giardia lamblia* (also called *G. intestinalis* and *G. duodenalis*) is a flagellate protozoa. Giardiasis is a worldwide diarrheal disease of mammals and some birds.

Clinical Signs and Diagnosis Diarrhea may be continuous or intermittent, is pasty to watery, yellow and may contain blood. Animals exhibit fever, dehydration, and depression. Chronic cases may result in a 'poor doer' syndrome with weight loss and unthriftiness.

Diagnosis is by identifying the motile trophozoites in fresh fecal mounts. Oval cysts can be floated with zinc sulfate solution (33%). Standard solutions tend to be too hyperosmotic and distort the cysts. Newer ELISA, and IFA tests are sensitive and specific.

Epizootiology and Transmission Giardia infection may occur at any age, but young animals are more susceptible. Giardia is quite prevalent in both beef and dairy calves in North America. Calves do not typically develop diarrhea due to giardiaisis until after 4 weeks of age. Chronic oocyst shedding is common. Transmission of the cyst stage is fecal–orally. Wild animals may serve as reservoirs.

Necropsy Findings This disease does not generally result in necropsy.

Prevention and Control Intensive housing and warm environments should be minimized. Cysts can survive in the environment for long periods of time but are susceptible to desiccation. Effective disinfectants include quaternary ammonium compounds, bleach (1:16 or 1:32), steam, or boiling water.

Treatment *Giardia* has been successfully treated with oral metronidazole. Benzimidazole anthelmintics are also effective but these are not approved for use in animals for this purpose.

Research Complications *Giardia* is zoonotic. Precautions should be taken when handling infected animals.

vi. NEOSPOROSIS

Etiology Neosporosis is a common, worldwide cause of bovine abortion caused by the protozoal species, *Neospora caninum*. Abortions have also been reported in sheep and goats. Neonatal disease is seen in lambs, kids, and calves.

Clinical Signs and Diagnosis Abortion is the only clinical sign seen in adult cattle, and occurs either sporadically, endemically, or as abortion storms. Bovine abortions occur between the 3rd and 7th month of gestation. Although infections in adults are asymptomatic, decreased milk production has been noted in congenitally infected cows in addition to abortion. *Neospora*-infected calves can be born asymptomatic. Weakness may be evident but this resolves. Rare clinical signs include exophthalmus or asymmetric eyes, weight loss, ataxia, hyperflexion or hyperextension of all limbs, decreased patellar reflexes, and loss of conscious proprioception, opisthotonus, and seizures.

Immunohistochemistry and histopathology of fetal tissue are the most efficient and reliable means of establishing a *post mortem* diagnosis. Serology (IFA and ELISA) is useful, including pre-colostral levels in weak neonates, but this indicates only exposure. Titers of dams will not be elevated at the time of abortion; fetal serology is influenced by the stage of gestation and course of infection. None of the currently available tests is predictive of disease.

Epizootiology and Transmission The parasite is now acknowledged to be widespread in dairy and beef cattle herds, and is considered a common cause of abortion in cattle. The life-cycle of *N. caninum* is complex and many aspects remain to be clarified. The definitive host is the dog (McAllister *et al.*, 1998); infective oocysts are shed in canine feces. Placental or aborted tissues are the most likely sources of infection for the definitive host and may also play a minor role in transmission to the intermediate hosts. The many intermediate hosts include ruminants, deer, and horses. The transplacental route is the major mode of transmission in dairy cattle and is responsible for perpetuated infection; infection is latent and life-long. Seropositive immunity does not protect a cow from future abortions. Many seropositive cows and calves will never abort or show clinical signs, respectively.

Necropsy Findings Aborted fetuses will usually be autolyzed. In those from which tissue can be recovered, tissue cysts are most commonly found in the brain. Cysts and tachyzoites of *N. caninum* cannot reliably be distinguished from those of *Toxoplasma gondii* at the light-microscopic level, and require ultrastructure or molecular techniques (IHC, PCR, etc.) for differentiation.

Differential Diagnoses Even when there is a herd history of confirmed *Neospora* abortions, leptospirosis, BVDV, IBRV, salmonellosis, and campylobacteriosis should be considered. BVDV in particular should be considered for abortion storms. Differentials for weak calves are BVDV, perinatal hypoxia following dystocia, bluetongue virus, *Toxoplasma*, exposure to teratogens, or congenital defects.

Prevention and Control The primary preventative measure is eliminating contact with contaminated dog feces. Dog populations should be controlled, and dogs and other canids should not have access to placentas or aborted fetuses, or to feed bunks and other feed storage areas. Preventative culling is not economically practical for most producers. A vaccine recently became available, although its efficacy is not well-established.

Treatment There is no known treatment or immunoprophylaxis.

vii. SARCOCYSTOSIS

Etiology Sarcocystosis is the disease caused by the cyst-forming sporozoan, *Sarcocystis*. Separate species of *Sarcocystis* infect sheep, goats, and cattle. Definitive hosts are carnivores and all ruminant species are intermediate hosts.

Clinical Signs and Diagnosis Clinical signs of sarcocystosis infection are seen in cattle during the stage when the parasite encysts in soft tissues. Most infections are asymptomatic. Fever, ataxia, symmetric lameness, tremors, tail switch hair-loss ('rat-tail'), excessive salivation, diarrhea, and weight loss occur. Abortions in cattle occur during the second trimester; small ruminants abort approximately 28 days after ingestion of the sporulated oocysts. Sarcocystis in sheep has been known to cause encephalomyelitis. Some sheep may lose wool after recovery from acute infection.

Definitive diagnosis is based on finding merozoites and meronts in fetal neural tissue lesions.

Epizootiology and Transmission Infection rates among cattle in the United States are estimated to be very high (Barr *et al.*, 1998; Dubey, 2005). Transmission is by ingestion of feed and water contaminated by feces of the definitive hosts. Dogs are the definitive hosts for the species infecting the smaller ruminants. Cats, dogs, and primates (including humans when *S. hominis* is involved) are the definitive hosts for the species infecting cattle.

Necropsy Aborted fetuses may be autolyzed. Lesions in neural tissues, including meningoencephalomyelitis, focal malacia, perivascular cuffing, neuronal degeneration, and gliosis, are most marked in the cerebellum and midbrain. Grossly, sarcocysts encysted in skeletal or cardiac muscle may resemble grains of rice. The histologic appearance of the sarcocysts is characteristic.

Pathogenesis Ingestion of muscle flesh from an infected ruminant results in intestinal infection and sarcocystis shedding in feces as sporocysts by the definitive hosts. The sporocysts are eaten by the ruminant, and several stages of development occur in endothelial cell of arteries, culminating in merozoites which enter soft tissues and subsequently encyst.

Prevention and Control Feed supplies of ruminants must be protected from fecal contamination by domestic and wild carnivores. These animals should be controlled and must not have access to carcasses.

Treatment Monensin fed during incubation is prophylactic but the efficacy in clinically affected cattle is not known. Amprolium (100 mg/kg, SID for 30 days) fed prophylactically in cattle and sheep has been shown to reduce illness and even protect experimentally infected animals (Merck Veterinary Manual Online, 2011).

viii. TOXOPLASMOSIS

Etiology Toxoplasmosis is caused by the obligate intracellular protozoan, *Toxoplasma gondii*, a coccidian parasite. Cats are the only definitive hosts and several warm-blooded animals, including ruminants, have been shown to be intermediate hosts. It is a major cause of abortion in sheep and goats and less common in cattle.

Clinical Signs and Diagnosis Toxoplasmosis is typically associated with placentitis, abortion, stillbirths, or birth of weak young (Underwood and Rook, 1992). It has also been shown to cause pneumonia and nonsuppurative encephalitis. Infection of the ewe during the first trimester usually leads to fetal resorption, during the second trimester leads to abortion, and during the third trimester leads to birth of weak or normal lambs with subsequent high perinatal mortality. Congenitally infected lambs may display encephalitic signs of circling, incoordination, muscular paresis, and prostration. Although infected adult sheep show no systemic illness, infected adult goats may die of toxoplasmosis.

Diagnosis may be difficult, but biological, serological, and histological diagnostic methods are helpful. Serological tests are the most readily available. Fetal thoracic fluid is especially useful in demonstrating serological evidence of exposure. *In vivo* tests for Toxoplasmosis include IHA, IFA, latex agglutination, or ELISA. Characteristic crescentic tachyzoites in impression smears of tissue can be utilized for diagnosis *post mortem*.

Epizootiology and Transmission This protozoan is considered ubiquitous. Fifty percent of adult western sheep and 20% of feedlot lambs have positive hemagglutination titers of 1:64 or higher (Kimberling, 1988). Transmission among the definitive host is by ingestion of tissue cysts. Transmission to ruminants is through ingestion of cat feces.

Necropsy Findings At necropsy, placental cotyledons contain multiple small white areas that are sites of necrosis, edema and calcification. Fetal brains may show non-specific lesions such as coagulative necrosis, nonsuppurative encephalomyelitis, pneumonia, myocarditis, and hepatitis. Giemsa-stained impression smears of retina, myocardium, liver, kidney, or brain provide a rapid means of diagnosis. Identification of the organism in tissue sections (especially the heart and the brain) also confirms the findings.

Pathogenesis The definitive hosts, felids, become infected by ingesting cyst stages in mammalian tissues, by ingesting oocysts in feces, and by transplacental transfer. Infected cats shed millions of oocysts in the feces but only for a few weeks in its life. Ruminants become infected by ingesting sporulated oocyst-contaminated water or feed. The ingested sporozoite invades invades the bloodstream and migrates to tissues such as the brain, liver, muscles, and placenta. Placental infection develops about 14 days after ingestion of the oocysts.

Differential Diagnoses Differentials for abortion include *Neospora caninum, Campylobacter, Chlamydophila*, and Query Fever.

Prevention and Control Feline populations on source farms must be controlled. Eliminating contamination of feed and water with cat feces is the best preventative measure. Sporulated oocysts can survive in soil and other places for long periods of time and are resistant to desiccation and freezing. Vaccines for abortion prevention in sheep are available in New Zealand and Europe.

Treatment Toxoplasmosis treatment is ineffective, although feeding monensin during pregnancy may be helpful (Underwood and Rook, 1992). However, monensin is not approved for this use in the United States.

Research Complications Because toxoplasmosis is zoonotic, precautions must be taken when handling tissues from any abortions or neurological cases. Infections in immunocompromised humans have been fatal.

ix. TRICHOMONIASIS

Etiology Trichomoniasis is a venereal disease of cattle caused by *Tritrichomonas* (also referred to as *Trichomonas*) *fetus*, a large, pear-shaped, flagellated protozoan which is an obligate parasite of the bovine reproductive tract. In the United States, trichomoniasis is a disease seen primarily in western beef herds.

Clinical Signs and Diagnosis Clinical signs include infertility manifested by low pregnancy rates as well as periodic pyometras and abortions during the first half of gestation. The abortion rate varies from 5% to 30%, and placentas will be expelled or retained. Infection with *T. fetus* causes no systemic signs. Affected cows will clear the infection over a span of months and maintain immunity for about 6 months but bulls may become chronic carriers.

Diagnosis is based on patterns of infertility and pyometras. Trichomonads may be identified or cultured from preputial smegma, cervicovaginal mucus, uterine exudates, placental fluids, or abomasal contents of aborted fetuses. Culturing must be done on specific media, such as Diamond's or modified Pastridge.

Epizootiology and Transmission All transmission is by venereal exposure from either breeding bulls or cows, or in some cases, contaminated breeding equipment.

Necropsy Findings Nonspecific lesions, such as pyogranulomatous bronchopneumonia of fetuses and placentitis, may be seen in aborted material; fetal lung and placenta are the most useful for culturing.

Differential Diagnosis Campylobacteriosis is the other primary differential for reduced reproductive efficiency of a herd.

Prevention and Control A bacterin vaccine is available. AI reduces but does not eliminate the disease. The use of younger vaccinated bulls is recommended in all circumstances. Culling chronically infected bulls is strongly recommended.

Treatment Imidazole compounds have been effective, but the use of these substances is not permitted in food animals in the United States. Therapeutic immunizations are worthwhile when a positive diagnosis has been made.

Research Complications Trichomonas should be considered whenever natural service is used and fertility problems are encountered.

b. Gastrointestinal Nematodiasis

Nematodes are important ruminant pathogens and result in acute, chronic, subclinical, and clinical disease in adults and adolescents. The major helminths may result in gastroenteritis associated with intestinal hemorrhage and malnutrition. The disease is associated with grazing exposure to infective larvae. Animals procured for research may have had exposure to these helminths. Mixed infections of these parasites are common. Generally, older animals develop resistance to some of the species; thus, animals between about 2 months and 2 years of age are most susceptible to infection. Because of the parasites' effects on the animals' physiology, infection in these younger animals is a major contributor to a cycle of poor nutrition and digestion, compromised immune responses, and impaired growth and development. Diagnosis is primarily based on fecal flotation techniques; however, because many of these nematodes have similarly appearing ova, hatching the ova and identifying the larvae is often required (Baermann technique). The pre-patent period for most nematode parasites is 2–3 weeks. A number of anthelmintics can be used to interrupt nematode life-cycles. (See McKellar and Jackson, 2004, and/or Sargison, 2012; Quinton *et al.*, 2004, for comprehensive reviews of treatment and control of nematodiasis.) Those nematodes with the highest potential for pathogenicity in sheep and goats include *Haemonchus contortus* (Barber-pole worm), *Teladorsagia* (formerly *Ostertagia*) *circumcincta* (Medium stomach worm), *Cooperia* (Small intestinal worms), *Trichostrongylus* spp. (Hair worms), *Oesophagostomum columbianum* (Nodule worm disease, pimply gut), *Cooperia curticei*, and *Strongyloides papillosus*. In cattle, clinical parasitism is often associated with *Haemonchus placei*, *Ostertagia*

ostertagi, *Trichostrongylus axei*, *Cooperia* spp., *Strongyloides* spp., and *Oesophagostomum* spp. Trichostrongyles such as *Ostertagia, Haemonchus, Trichostrongylus, Cooperia, Dictyocaulus*, and *Oesophagostomum* may undergo seasonal hypobiosis or arrested development of the life-cycle. In the northern hemisphere larvae arrest and accumulate inside grazing animals in the fall, allowing the parasite to overwinter in the animal protected from winter pasture conditions.

Rotation of anthelmintics due to inherent resistance development and appropriate pasture management are key principles in parasite control.

i. DICTYOCAULOSIS (LUNGWORMS) Dictyocaulosis, or lungworm infestation, causes clinical respiratory signs in ruminants. In sheep, *Dictyocaulus filaria, Protostrongylus rufescens*, and *Muellerius capillaris* cause disease; *Dictyocaulus* is the most pathogenic. Infections in goats are uncommon. *Dictyocaulus viviparus* is the only lungworm found in cattle. Infections with these parasites in the United States tend to be associated with cool, moist climates. Lungworms induce a severe parasitic bronchitis (known as 'husk,' or verminous pneumonia) in sheep between approximately 2 months and 18 months of age. Sheep and cattle infected with any of the species of lungworms may display coughing, dyspnea, nasal discharge, weight loss, unthriftiness, and occasionally fever. Diagnosis is suggested by clinical signs and is confirmed by identifying larvae in the feces using the Baermann technique or adults in lung tissue samples.

Dictyocaulus has a direct life-cycle. The adult worms reside in the large bronchi, produce embryonated eggs that are coughed up and swallowed; the eggs then hatch in the intestines and larvae are expelled in the feces. The expelled larvae are infectious in about 7–10 days, and after ingestion, penetrate the intestinal mucosa and move through the lymphatics and blood into the lungs where they develop into adults in about 5 weeks. *Protostrongylus* and *Muellerius* require a snail or slug as an intermediate host.

Necropsy lesions include bronchiolitis and bronchitis, atelectasis, and hyperplasia of peribronchiolar lymphoid tissue.

Prevention and control of the disease involves appropriate pasture management to minimize exposure of young, susceptible animals. Elimination of intermediate hosts is important in sheep and goat pastures. Infected animals can be treated with anthelmintics such as ivermectins, milbemycins, or levamisole. An effective irradiated larval vaccine is marketed in the United Kingdom and Western Europe.

ii.* PARELAPHOSTRONGYLUS TENUIS *(MENINGEAL WORM, BRAIN WORM) *Parelaphostrongylus tenuis* is a nematode parasite common to white tail deer. Sheep and goats, camelids, elk, caribou, and moose may be aberrant hosts. Adult worms in meningeal tissue lay eggs that develop into first stage larvae that migrate through the bloodstream to the lungs. Larvae are coughed up, swallowed, and are expelled in the feces where they are ingested by snails and slugs and develop into second- and third-stage larva. Following accidental ingestion of the gastropods, the larvae migrate to the brain. Neurological and behavioral signs are rare and relatively mild in white tail deer but can be severe in aberrant hosts, sometimes resulting in paraplegia. Goats have been reported to develop vertically oriented pruritic skin lesions on the neck, shoulders, and back (Smith and Sherman, 2009).

c. Cestodiasis (Tapeworms)

i. MONIEZIA EXPANSA, THYSANOSOMA ACTINOIDES Tapeworms are rarely of clinical or economic importance. In younger animals, heavy infections result in pot bellies, constipation or mild diarrhea, poor growth, rough coat, and anemia. *Moniezia expansa*, and less commonly *Moniezia benedini*, inhabit the small intestines of grazing ruminants. *Thysanosoma actinoides* or the fringed tapeworm resides in the duodenum, bile duct, and pancreatic duct of sheep and cattle raised primarily west of the Mississippi River. All have indirect life-cycles. No clinical or pathological sign is usually observed with tapeworm infection, however, *Thysanosoma* infections may result in liver condemnation at slaughter. Diagnosis is made by observing segments in manure or the characteristic triangular-shaped eggs in fecal flotation examinations. Albendazole is an effective cestocide.

ii. ABDOMINAL OR VISCERAL CYSTICERCOSIS AND ECHINOCOCCOSIS (HYDATID CYST DISEASE) Tapeworm eggs from the primary host contain an oncosphere, which hatches and penetrates the intestinal wall when ingested by the intermediate host. The second-stage larva develops in the intermediate host and is called a metacestode which is a space occupying cystic structure. Metacestode forms are tapeworm specific and include the cysticercoid (microscopic and in small intermediate hosts such as insects of mites); cysticercus (small blister to ping-pong ball sized structures); coenurus (usually intracranial in the host) and hydatid cysts (usually intraabdominal in the host). The coenurus and hydatid cysts can become quite large, contain multiple larvae, and can locally bud and spread. When the metacestode form is ingested by the primary host, the larval brood capsules containing protoscolices evaginate to form the tapeworm head called the scolex.

Abdominal or visceral cysticercosis is an occasional finding in ruminants at slaughter. The 'bladder worms' typically affect the liver or peritoneal cavity and are caused by the larval form (metacestode) of *Taenia*

hydatigena, the common tapeworm of the dog family. The larval intermediate of another tapeworm of canids, *Echinococcus granulosus*, also may form hydatid cysts, particularly in liver and lungs. Ruminants are intermediate hosts of both parasites, and are infected by feed or water contaminated with gravid segments or ova. Although larval migration may cause nonspecific signs such as anorexia, hyperthermia, and weight loss, affected animals are usually asymptomatic. Infestation is usually diagnosed at necropsy or slaughter, and may result in condemnation of carcasses. Minimizing exposure to canine feces-contaminated feeds and water effectively interrupts the life-cycle. Research animals may have been exposed prior to purchase.

iii. COENUROSIS (GID) *Coenurus cerebralis*, the larval form of the tapeworm of domestic dogs, humans, and some wild carnivores, *Taenia (Multiceps) multiceps* is the causative agent of the rare condition called Gid. The disease occurs in ruminants as well as many other mammalian species. The larval parasite, ingested from fecal-contaminated food and water, invades the brain and spinal cord and develops as a bladderworm that causes pressure necrosis of the nervous tissues. The resultant signs of hyperesthesia, meningitis, paresis, paralysis, ataxia, and convulsions are observed. Diagnosis is usually made at necropsy. Eliminating transfer from the canid hosts prevents the disease.

d. Trematodes

i. FASCIOLIASIS (LIVER FLUKE DISEASE)

Etiology Liver flukes are an important cause of acute and chronic disease in grazing sheep and cattle. In the continental U.S., *Fasciola hepatica* infections are primarily seen in southeastern and western states. *Fascioloides magna* infections are typically seen in the Texas; Gulf coast; Great Lakes; and northwestern states where ruminants share pasture with deer, elk, and moose. *Dicrocoelium dendriticum* infections occur primarily in the eastern U.S. and Atlantic provinces of Canada, however *Dicrocelium* also occurs in areas of Europe and Asia. Liver fluke eggs are passed in the bile and feces and hatch in 2–3 weeks to form the free-swimming miracidia. It is important to note that each fluke egg represents the source of eventually thousands of cercariae or metacercariae. The miracidia penetrate the body of an intermediate host (usually freshwater snails) and develop through sporocysts and rediae stages, finally forming cercariae. The cercariae leave the intermediate host, swim to grassy vegetation, and become cyst-like metacercariae, which may remain in a dormant stage on the grass for 6 months or longer until ingested by a ruminant. The ingested metacercariae penetrate the small-intestinal wall, migrate through the abdominal cavity to the liver where they locate in a bile duct, mature and remain for up to 4 years.

Clinical Signs Acute liver fluke disease is related to the damage caused by the migration of immature flukes which leads to liver inflammation, hemorrhage, necrosis, and fibrosis. *F. magna* infections in sheep and goats can be fatal as the result of just one fluke tunneling through hepatic tissue. In cattle, infections are often asymptomatic due to the host's encapsulation of the parasite. Liver fluke damage may predispose to invasion by anaerobic *Clostridium* species such as *C. novyi* that could lead to fatal Black Disease or bacillary hemoglobinuria. Chronic disease may result from fluke-induced physical damage to the bile ducts and cholangiohepatitis. Blood loss into the bile may lead to anemia and hypoproteinemia. Liver damage also is evidenced by increases in liver enzymes such as gamma glutamyl transferase (GGT). Persistent eosinophilia is also seen with liver fluke disease. Other clinical signs of liver fluke disease include anorexia, weight loss, unthriftiness, edema, and ascites. At necropsy, livers will be pale, friable and may have distinct migration tunnels along the serosal surfaces. Bile ducts will be enlarged and areas of fibrosis will be evident.

Diagnosis can be made from clinical signs and *post mortem* analyses. Blood chemistries suggestive of liver disease and eosinophilia support the diagnosis. Liver fluke control involves treatment of infected animals, reduction of the intermediate host population and/or restriction of animal access to snail-infested pastures. In a laboratory setting, liver fluke infection is unlikely. Nonetheless, incoming animals from pasture environments may be infected. Liver flukes can be treated with the anthelmintic clorsulon or albendazole.

e. Mites

i. MANGE Mites infesting ruminants include those of the genera *Sarcoptes*, *Psoroptes*, *Chorioptes*, and *Demodex*. Depending on the species of mite, signs range from relatively mild flaking and itching to intense pruritus, extensive skin damage, and self-mutilation. Papules, crusts, alopecia, and secondary dermatitis are seen. In more severe cases, anemia, disruption of reproductive cycles, and increased susceptibility to other diseases may also develop.

In the United States, infections of *Sarcoptes* and *Psorergates* must be reported to animal health officials. These mites cause severe signs in cattle, sheep, and goats, but fortunately are rare in North America. Diagnosis is based on clinical signs, examination of skin scrapings, and response to therapy.

Chorioptic mange ('barn itch' or 'leg mange') is common in ruminants, particularly in winter months when animals are housed. Chorioptes species (*C. bovis, C. ovis, C. caprae*) are relatively specific to their hosts and do not invade the epidermal tissue but rather feed off dead skin. The lower limbs, tail, perineum, and scrotum

are most often affected. Pruritis is variable and may be accompanied by papules, crustiness, and alopecia.

Historically, insecticides such as coumaphos, diazinon, and lime sulfur have been used to treat mange in ruminants. These treatments have been largely replaced by the use of macrocyclic lactone anthelmintics (ivermectin), either by injection or topically.

Although relatively uncommon, demodectic mange occurs in cattle, sheep, and goats. Animals develop nodular lesions, typically around the face, head, and shoulders. No effective treatment for demodectic mange in large animals has been found. The differential for mite infestations is pediculosis. In goats, the psoroptic mite, *Psoroptes cuniculi*, commonly occurs in the ear canal and causes head shaking and scratching.

f. Lice/Ticks

i. PEDICULOSIS (LICE) Lice infecting ruminants are of the order *Mallophaga*, the biting or chewing lice (genus *Damalina*), and *Anoplura*, the sucking lice (genus *Linognathus*). These are wingless insects. Lice produce a seasonal (winter to spring) chronic dermatitis.

Pruritus is the most common sign and often results in alopecia and excoriation. The host's rubbing and grooming may not correlate with the extent of infestation. Hairballs can result from overgrooming in cattle. In severe cases, the organisms can lead to anemia, weight loss, damaged wool in sheep, and damaged pelts in other ruminants. Young animals with severe infestations of sucking lice may become anemic or even die. Pregnant animals with heavy infestations may abort. In sheep infected with the foot louse, lameness may result.

Lice are generally species specific, and those infecting ruminants are usually smaller than 5 mm. Transmission is primarily by direct contact between animals or by attachment to flies or fomites.

Biting or chewing lice inhabit the host's face, lower legs, and flanks and feed on epidermal debris and sebaceous secretions. Sucking lice inhabit the host's neck, back, and body region and feed on blood. Lice eggs or nits are attached to hairs near the skin. Three nymphal stages, or instars, occur between egg and adult, and the growth cycle takes about 1 month for all species. Lice cannot survive for more than a few days off the host. All ruminant mite infestations are differentials for the clinical signs seen with pediculosis.

Lice are effectively treated with a variety of insecticides including coumaphos, dichlorvos, crotoxyphos, avermectin, and pyrethroids. Label directions should be read and adhered to including withdrawal times. Only products approved for lactating or dry dairy cattle should be used on female dairy animals >20 months of age. Treatments must be repeated at least twice at intervals appropriate for nit hatches (about every 16 days) because nits will not be killed. Fall treatments are useful in managing the infections. Systemic treatments in cattle are contraindicated when there may be concurrent larvae of cattle grubs (*Hypoderma lineatum* and *H. bovis*). Back rubbers with insecticides, capitalizing on self-treatment, are useful for cattle. Sustained release insecticide-containing ear tags are approved for use in cattle.

ii. TICKS (ARACHNIDS)

Etiology Ruminants are susceptible to many species of Ixodidae (hard shell ticks) and Argasidae (soft-shell ticks). Several diseases, including anaplasmosis, babesiosis, and Q fever are transmitted by ticks.

Clinical Signs and Diagnosis Tick infestations are associated with decreased productivity, loss of blood and blood proteins, transmission of diseases, debilitation, and even death. Feeding sites on the host vary with the tick species. Ticks are associated with an acute paralytic syndrome called Tick Paralysis. This disease is characterized by ascending paralysis and may lead to death if the tick is not removed before the paralysis reaches the respiratory muscles. Diagnosis is based on identification of the species.

Epizootiology and Transmission Ticks are not as host specific as lice. Ticks are classified as one-host, two-host, or three-host ticks which refers to whether they drop off the host between larval and nymphal stages to molt.

Treatment Ticks can be treated using systemic or topical insecticides.

g. Other

i. NEW WORLD SCREWWORM The New World Screw Worm, *Cochliomyia hominivorax*, is a parasitic fly whose larvae are known to eat the living tissue of warm-blooded animals. Although eradicated from the United States, it is present in the New World tropics particularly Mexico and Central America. Screwworms are a reportable species to the state veterinarian in the United States if discovered on livestock.

ii. NASAL BOTS (NASAL MYIASIS, HEAD GRUBS) Nasal myiasis is a chronic rhinitis and sinusitis caused by the larval forms of the botfly, *Oestrus ovis*. The botfly deposits eggs around the nostrils of sheep. The ova hatch and the larvae migrate throughout the nasal cavity and sinuses, feeding on mucus and debris. In 2–10 months, the larvae complete their growing phase, migrate back to the nasal cavity, and are sneezed out. The mature larvae penetrate the soil and pupate for 1–1.5 months and emerge as botflies. Clinically, early in the disease course, animals display unique behaviors such as stamping, snorting, sneezing, and rubbing their noses against each other or objects.

Hypersensitivity to the larvae occurs (Dorchies *et al.*, 1998). Later, mucopurulent nasal discharges will be

observed associated with the larval-induced inflammation of mucosal linings. At necropsy, larvae will be observed in the nasal cavity or sinuses. Mild inflammatory reactions, mucosal thickening and exudates will accompany the larvae. The disease is diagnosed by observing the behaviors or identifying organisms at necropsy. Up to 80% of a flock will potentially be infected; treatment should be employed on the rest of the flock. Ivermectins and other insecticides will eliminate the larvae; but treatment should be done in the early fall, when larvae are small. Fly repellents may be helpful at preventing additional infections.

iii. SHEEP KEDS ('SHEEP TICK') In sheep and goats, sheep keds produce a chronic irritation and dermatitis with associated pruritus. The disease is caused by *Melophagus ovinus*, which is a flat, brown blood-sucking, wingless fly; the term 'sheep tick' is incorrectly used. The adult fly lives entirely on the skin of sheep. Females mate and produce 10–15 larvae following a gestation of about 10–12 days. The larvae attach to the wool or hair, and pupate for about 3 weeks. The adult female feeds on blood and lives for 4–5 months, and the life-cycle is completed in about 5–6 weeks. Infection is highest in fall and winter. Pruritus develops around the neck, sides, abdomen, and rump. In severe cases, anemia may occur. Keds can transmit Bluetongue Virus. Keds are diagnosed by gross or microscopic identification. Ivermectin or other insecticides are useful treatment agents.

4. Fungal

a. Dermatophytes (Ringworm)

Etiology Dermatophytosis, infections of the keratinized layers of skin, are caused mostly by species of the genuses *Trichophyton* and *Microsporum*. The primary causes in sheep are *Trichophyton mentagrophytes* and *T. verrucosum*. In goats, the agents are *T. mentagrophytes*, *Microsporum canis*, *M. gypseum*, and *T. verrucosum*. In cattle, *T. verrucosum* is the primary causative agent. Dermatophytosis is a common fungal infection of the epidermis of cattle and less common in sheep and goats.

Clinical Signs and Diagnosis Multiple, gray, crusty, circumscribed, hyperkeratotic lesions are characteristic of infection. Lesions will vary in size. In all ruminants, lesions will be around the head, neck, and ears. In goats and cattle, lesions will extend down the neck, and in cattle, lesions develop particularly around the eyes, and on the thorax. Cattle lesions are unique in the marked crustiness; hair shafts will become brittle and break off. Intense pruritus is often associated with the alopecic lesions.

The disease can be diagnosed by microscopic identification of hyphae and conidia on the hairs following skin scraping and 20% potassium hydroxide digestion. Dermatophyte Test Media (DTM) culture are the most reliable means to diagnose the fungus. Broken hairs from the periphery of the lesion are the best sources of the fungus.

Epizootiology and Transmission Younger animals are more susceptible, and factors such as crowding, indoor housing, warm and humid conditions, and poor nutrition are also important. Transmission is by direct contact or by contact with contaminated fomites, such as equipment, fencing, or feed bunks.

Treatment Spontaneous recovery occurs in all species in 1–4 months. Immune mechanisms are not well understood and immunity may not be of long duration. Recovery is enhanced by exposure to sunlight, correcting nutritional deficiencies and improving housing and ventilation problems. A number of topical treatments, such as 2–5% lime–sulfur solution, 3% Captan, iodophores, thiabendazole, and 0.5% sodium hypochlorite can be used. In severe cases, systemic therapy with griseofulvin may be successful.

Prevention and Control The animals' environment and overall physical condition should be reassessed with particular attention to ventilation, crowding, sanitation, and nutrition. Pens should be thoroughly cleaned and disinfected.

Research Complications Ringworm is a zoonotic disease.

B. Genetic/Metabolic/Nutritional/Management-Related Diseases

1. Genetic Diseases

a. Entropion

Inverted eyelids are a common inherited disorder of lambs and kids of most breeds. Generally, the lower eyelid is affected and turns inward causing various degrees of trauma to the conjunctiva and cornea. Young animals will display tearing, blepharospasm, and photophobia initially. If left uncorrected, corneal ulcers, perforating ulcers, uveitis and blindness may occur. Placing a suture or surgical staple in the lower eyelid and the cheek, effectively anchoring the lid in an everted position successfully treats the condition.

b. Beta Mannosidosis of Goats

Beta mannosidosis is an autosomal recessive lysosomal storage disease of goats. The disease affects kids of the Nubian breed and is identified by intention tremors and difficulty or inability of newborns to stand. Newborn kids are unable to rise and have characteristic flexion of the carpal joint and hyperextension of the pastern joint. Kids are born deaf with other musculoskeletal deformities such as a domed skull, small narrow muzzle, enophthalmus, and a depressed nasal bridge (Smith and Sherman, 2009). Carrier adults can be identified by plasma measurements of beta mannosidase activity.

c. Congenital Myotonia of Goats

Caprine congenital myotonia is an inherited autosomal dominant disease that affects voluntary striated skeletal muscles. Goats with this disease are commonly known as 'fainting' goats. Fainting is actually transient spasms of skeletal musculature brought about by visual, tactile, or auditory stimuli (Smith and Sherman, 2009). Contractions of skeletal muscle are sustained for up to 1 min. Kids exhibit the condition by 6 weeks of age, and males appear to exhibit more severe clinical signs than females.

d. Polled Intersex Goats

Several western European goat breeds (Saanen, Alpine, Toggenburg) exhibit a well-described genetic relationship between the polled (hornless) phenotype and intersex (or hermaphrodite) characteristics. A gene deletion on chromosome 1 affects the regulation of both horn bud and fetal ovarian development, resulting in genetically female animals who exhibit masculine characteristics such as enlarged clitoris, decreased anogenital distance, and muscular neck development. These animals are not fertile, and testosterone production often results in characteristic male odor and aggressive behavior (Smith and Sherman, 2009).

e. Inherited Conditions of Cattle

i. CONGENITAL ERTHYROPOIETIC PORPHYRIA

Congenital Erthyropoietic Porphyria (CEP) is a rare autosomal recessive disease of cattle seen primarily in Holsteins, Herefords, and Shorthorns. In the homozygous recessive animal, reddish-brown discoloration of teeth and bones is a characteristic as are discolored urine, general weakness and failure to thrive, photosensitization and photophobia. Porphyrins are excreted in varying amounts in the urine and the discoloration fluoresces under a Woods lamp. Bones are fragile compared to those of normal animals. A regenerative anemia occurs as the result of the shortened life span of erythrocytes due to accumulations of porphyrins. The genetic defect is associated with low activity of an essential enzyme, uroporphyrinogen III synthase, in the porphyrin–heme synthesis pathway in erythrocytic tissue. Heterozygotes may have milder clinical signs.

ii. OTHER INHERITED CONDITIONS OF CATTLE

Many other genetic defects, in all major organ systems, have been described in numerous breeds of cattle and are described in detail elsewhere (Smith, 2009). The bovine genome continues to be further characterized and more linkage maps and gene locations will be forthcoming (Womack, 1998). Some bovine genetic defects are also regarded as models of genetic disease, such as leukocyte adhesion deficiency and citrullinemia of Holstein cattle. Some of the more commonly reported defects include syndactyly and complex vertebral malformation in Holstein and other breeds, arthrogryposis multiplex in Angus, lysosomal storage diseases such as alpha-mannosidosis in some beef breeds, and progressive degenerative myeloencephalopathy ('weaver') in Brown Swiss.

Inherited periodic spasticity ('crampy syndrome') is a relatively common inherited trait in dairy cattle breeds, particularly Holsteins. Affected cattle develop muscle spasms in the hip and upper leg between 3 and 8 years of age. During a spasm, animals will typically extend or flex one rear leg and shake the leg for 15–30 s. The disease is progressive over the course of 1–2 years, and is thought to be transmitted by a single recessive gene.

f. Congenital Dyshormonogenetic Goiter of Sheep

A defect in the synthesis of thyroid hormone has been identified in Merino sheep (Radostits *et al.*, 2007). It has also been identified as an autosomal recessive disease in Corriedale, Dorset Horn, Merino, and Romney sheep and Saanen dwarf goats. Lambs and goats born with the defect have enlargement of the thyroid gland, a silky appearance to the wool and a high degree of mortality. Edema, bowing of the legs, and facial abnormalities have also been noted in animals with this disorder. Immaturity of the lungs at birth causes neonatal respiratory distress and results in dyspnea and respiratory failure.

g. Spider Lamb Syndrome (Hereditary Chondrodysplasia)

Spider lamb syndrome is an inherited, often lethal, musculoskeletal disorder primarily occurring in Suffolk and Hampshire breeds. Severely affected lambs die shortly after birth. Animals that survive the perinatal period develop angular limb deformities, scoliosis, and facial deformities. Muscle atrophy is common. Diagnosis can be based on typical clinical signs, which are similar to those seen with Marfan syndrome in humans (Rook *et al.*, 1986). Long-term survival is rare, and treatment is unsuccessful.

h. Other Inherited Conditions of Sheep

Gangliosidosis (β-galactosidase deficiency) has been documented in Suffolk and Coopworth–Romney sheep; gamma-glutamyl carboxylase deficiency in the Rambouillet breed; globoid cell leukodystrophy (Krabbe's disease or galactocerebroside beta-galactosidase deficiency) in polled Dorset sheep; ceroid lipofuscinosis in South Hampshire, Swedish Landrace, and Rambouillet sheep; neuraxonal dystrophy of the Suffolk breed; and primary cerebellar degeneration of Merino and Charollais sheep.

2. *Metabolic Diseases*

a. Abomasal Disorders

i. ABOMASAL, DUODENAL ULCERS Abomasal and duodenal ulcers occur more frequently in preweaned beef calves and adult dairy cattle than in sheep and goats. Ulcers may be associated with abrupt dietary changes, or stress due to over-crowding, recent transport or recent parturition. Concurrent disease, such as Salmonellosis, Bluetongue or *Clostridium perfringens* abomasitis or overuse of anti-inflammatory drugs also may lead to ulcer formation. In older adult cattle, abomasal lymphoma may be the underlying condition. Ulcers are classified as perforating or non-perforating, and non-perforating ulcers are further classified as non-bleeding or bleeding.

Clinical signs vary with the type of ulcer. Non-perforating ulcers may simply result in reduced feed intake and reduced milk production, or chronic hemorrhage may lead to anemia. Dark feces or melena and abdominal pain may be observed. Arched back, restlessness, kicking at the abdomen, bruxism and anorexia are common signs of abdominal pain (Fecteau and Whitlock, 2009). Fecal occult blood is one of the more reliable diagnostic tests. Marked elevation of BUN with a normal serum creatinine is supportive of a bleeding ulcer. Ulcers often are asymptomatic in calves, but perforation with peritonitis is more common than hemorrhage.

Treatment for ulcers include gastrointestinal protectants and antihistamines. Anemia may be symptomatically treated with parenteral iron injections and anabolic steroids. Preventative measures in cattle herds include minimizing stress to calves, and striving for a herd free of BLV.

ii. ABOMASAL EMPTYING DEFECT Abomasal emptying defect of sheep is a sporadic syndrome associated with abomasal distention and weight loss. Suffolks tend to be especially predisposed, although the disease has been diagnosed in Hampshires, Columbia, and Corriedales. The mechanism of the disease is unknown. Research has shown a link to a defect in the autonomic nervous system, dyautonomia and possible neurotoxicosis (Pugh and Baird, 2012). Affected animals will exhibit a gradual weight loss with a history of normal appetites and normal feces. Ventral abdominal distension associated with abomasal accumulation of feedstuffs will be apparent. Diagnosis is primarily based on history and clinical signs. Elevations in rumen chloride concentrations (>15 mEq/l) are commonly found. Radiography or ultrasonography may be helpful in identifying the distended abomasum. Abomasal emptying defect is eventually fatal. Treatment with metoclopramide and mineral oil may be helpful in early disease.

iii. ABOMASAL DISPLACEMENT Displaced abomasum (DA) is a sporadic disorder usually associated with dairy cows in early lactation but the condition can occur in any stage of lactation, in young calves and in bulls. Left displacement (LDA) is the most common presentation (about 90%). Displacement to the right (RDA) may be further complicated by abomasal volvulus (RAV), a surgical emergency. The DA occurs because of gas accumulation within the abomasum, often associated with periparturient hypocalcemia, allowing the abomasum to migrate up from its normal ventral location to either the right or left lateral abdomen.

Clinical signs include anorexia, lack of cud chewing, decreased frequency of ruminal contractions, shallow respirations, increased heart rate, evidence of abdominal pain, and decreased milk production. Diagnosis is based on characteristic areas of tympanic resonance during auscultation-percussion of the lateral to ventro-lateral abdomen ('pings'), ruminal displacement palpated per rectum, and clinical signs. Clinical chemistry findings include hypoglycemia and ketonuria and moderate to severe electrolyte and acid–base abnormalities.

Risk factors for DA include parity (multiparous cows having higher incidence), twinning, breed, season (higher incidence in winter), the practice of 'lead feeding' concentrate feeds, and many disorders including hypocalcemia, retained placenta, metritis, and mastitis. Body size and conformation may be factors, indicating the possibility of genetic predisposition.

Treatments include surgical and nonsurgical correction of LDA with the former having a better chance of permanent correction. Emergency surgery is necessary for RAV because the disorder can be fatal within 72 h. Reoccurrence is rare after surgical correction. Electrolyte and acid–base imbalances are likely in severe cases and especially RAV. Prevention includes reducing stress in the periparturient period, greater care in the introduction and feeding of concentrates, and reducing incidence of predisposing diseases noted above (Geishauser *et al.*, 2000).

b. Rumen and Reticulum Disorders

i. BLOAT Bloat or rumen tympany refers to an excessive accumulation of gas in the rumen. The condition most frequently occurs in animals that recently have been fed abundant quantities of succulent forages or grains. Bloat is classified into two broad categories: frothy bloat and free-gas bloat. Frothy bloat is associated with ingestion of feeds that produce a stable froth that is not easily expelled from the rumen. Fermentation gases such as CO_2 and methane incorporate into the froth and over-distend the rumen, eventually compromising respiration by limiting diaphragm movement. Typical feedstuffs that cause frothy bloat include fresh or dried legumes (alfalfa or clover) or cereal grains (especially

finely ground corn and barley). Free-gas bloat is more often related to rumen atony or physical/pathological problems preventing normal gas eructation. Some causes of free-gas bloat include esophageal obstructions (foreign bodies such as boluses, apples, etc.), positional (e.g., being trapped in a position that precludes eructation), tumors, abscesses, enlarged cervical or thoracic lymph nodes, vagal nerve paralysis or injury, traumatic reticulitis, hypocalcemia, and central nervous system conditions affecting eructation reflexes.

Clinically, rumen distension will be observed in the left paralumbar fossa. Additional signs may include colic-like pain of the abdomen and dyspnea. Passage of a stomach tube helps to differentiate between free-gas bloat and frothy bloat. Obstructions may require manual removal prior to the use of a stomach tube; be sure to consider rabies prior to manual extraction. With free-gas bloat, expulsion of gas through the stomach tube aids in treatment of the disorder. Once rumen distension is alleviated with free-gas bloat, the underlying cause must be investigated to prevent reoccurrence. Frothy bloat is more difficult to treat as the foam blocks the stomach tube. Addition of mineral oil, surfactants or antifermentative compounds via stomach tube may help break down surface tension, allowing gas to be expelled. In acute, life-threatening cases of bloat, treatment should be aimed at alleviating rumen distension by placing a trocar or surgical rumenotomy into the rumen via the left paralumbar fossa. Feeding management is critical in controlling the incidence of bloat; limiting the consumption of feedstuffs known to induce bloat can prevent the disease. In addition, feeding poloxalene will decrease the incidence of legume bloat. Ionophores such as monensin or lasalocid can reduce the incidence of frothy bloat from either legume or concentrate feeds (Streeter, 2009).

ii. LACTIC ACIDOSIS: ACUTE AND SUBACUTE

Lactic acidosis or rumen acidosis may be acute or subacute and typically affects cattle or sheep consuming relatively energy-dense diets such as feedlot animals or dairy cows. Acute metabolic disease usually is caused by sudden engorgement on grains or other highly fermentable carbohydrate sources or by a rapid change from a diet containing high roughage content to one containing a relatively high proportion of grain. Common cereal grains and feedstuffs such as sugar beets, molasses, and potatoes predispose to acidosis. Ingestion of large amounts of these carbohydrate-rich feeds causes proliferation of gram-positive bacteria leading to rapid fermentation with an increase in lactic acid production and reduction of rumen pH. Subsequently gram-negative bacteria die in large numbers and release endotoxin. The high osmolarity of rumen contents results in accumulation of fluid, and the low pH and perturbed rumen microflora cause rumen mucosal inflammation. Sequelae of acidosis include rumenitis, abomasal ulcers, liver abscesses, lung abscesses leading to episodes of epistaxis, laminitis from absorbed toxins, and polioencephalomalacia from the inability of the altered rumen bacterial populations to produce sufficient B-complex vitamins.

Clinical Signs and Diagnosis In the case of acute ruminal acidosis, animals will become anorexic, depressed, and weak within 1–3 days after the initial insult. Incoordination, ataxia, dehydration and hemoconcentration (hypovolemic and endotoxic shock), rapid pulse and respiration, diarrhea, abdominal pain, and lameness may be noted. Rumen distension (bloat) may also be observed. Rumen pH, which is normally above 6.0 will drop to less than 5.0 and in severe cases may achieve levels as low as 3.8. Similarly, urine pH will become acidic, blood pH will drop below 7.4 and hematocrit will appear to increase due to the relative hemoconcentration. Subacute ruminal acidosis (SARA syndrome) has more subtle signs, but may include intermittent bouts of anorexia and diarrhea, depressed milk fat percentage in dairy cows, sporadic cases of epistaxis and an increased incidence of laminitis. Subacute acidosis is best diagnosed by performing rumenocentesis in a sample of affected cows (Krause and Oetzel, 2006).

Necropsy Findings Necropsy findings will be determined by severity and time-course of the incident. Acute lactic acidosis will cause inflammation, swelling and necrosis of rumen papillae and abomasal hemorrhages and ulcers. More chronic or subacute acidosis will result in parakeratosis of ruminal papillae. Papillae will be short (blunted), thickened, and rough. They will frequently be dark in color, and multiple papillae will clump together. Abscesses may be present in lung and liver. Stellate ruminal scars are telltale signs of previous episodes of acute acidosis.

Treatment Treatment must be applied early in the case of acute acidosis. In early hours of severe carbohydrate engorgement, rumenotomy and evacuation of the contents is appropriate. The patient should be given mineral oil and antifermentatives to prevent the continued conversion of starches to acids and the absorption of the metabolic products; animals in hypovolemic shock should be given hypertonic saline. Bicarbonate or other antacids such as magnesium carbonate or magnesium oxide introduced into the rumen will aid in adjusting rumen pH. Furthermore, animals can be given oral tetracycline or penicillin that will decrease the gram-positive bacterial population. In the case of subacute acidosis, correction of ration formulation and delivery to provide a higher proportion of effective fiber is critical. In the case of animals receiving chopped or processed forages, provision of long hay may be beneficial. Buffers such as sodium bicarbonate or sodium sesquicarbonate also can be incorporated into the rations or provided free-choice.

iii. TRAUMATIC RETICULITIS-RETICULOPERITONITIS (HARDWARE DISEASE)

Etiology This is a disease primarily of cattle related to their relatively indiscriminant feeding behavior. The disease is rarely seen in smaller ruminants.

Clinical Signs Clinical signs range from asymptomatic to severe, depending on the penetration and damage by the foreign object after settling in the animal's reticulum. Many signs during the early, acute stages will be attributable to pain and rumen stasis and range from anorexia, listlessness and an arched back, grunting forced to move, a painful response to pressure on the xyphoid or pinching of the withers, fever, abrupt decrease in production, decrease or cessation of ruminal contractions, bloat, regurgitation, tachypnea, and tachycardia. The prognosis is poor when peritonitis becomes diffuse. Sudden death can occur if the heart, coronary vessels, or other large vessels are punctured by the migrating object.

Epizootiology and Transmission This is a noncontagious disease. The occurrence is directly related to sharp or metallic indigestible linear items in the feed or environment that the cattle can swallow. Multiple cases may present if dairy or feedlot cattle consuming chopped feeds such as silage are presented with shards of metal (e.g., fencing material) which has been processed along with the feedstuffs.

Necropsy Findings In severe cases, these include extensive inflammation throughout the cranial abdomen, malodorous peritoneal fluid accumulations, and lesions at the reticular sites of migration of the foreign objects. Pericarditis and/or cardiac puncture may be present in those animals succumbing to sudden death.

Pathogenesis Consumed objects initially settle in the rumen, but are deposited in the reticulum during the digestive process and normal contraction may eventually lead to puncture of the reticular wall. This sets off a localized inflammation, or a more generalized peritonitis. Further damage may result from migration and penetration of the diaphragm, pericardium, and heart. Diagnosis is based on clinical signs and reflection of acute or chronic infection on the hemogram. Ultrasound and abdominocentesis may be useful.

Differential Diagnoses These include abomasal ulcers, hepatic ulcers, neoplasia (such as lymphoma in older animals or intestinal carcinoma), and cor pulmonale. Infectious diseases that are differentials include systemic leptospirosis and internal parasitism. Diseases causing sudden death may need to be considered.

Prevention and Control This problem can be prevented entirely by elimination of sharp objects in cattle feed and pasture environments. Adequately sized magnets placed in feed-handling equipment and forestomach magnets (placed *per os* with a balling gun in youngstock at 6–8 months of age) are also significant prevention measures. However, only a single magnet should ever be placed in an animal. The magnets are very strong, and can trap forestomach wall between them resulting in tissue necrosis and perforation. A compass placed near the xiphoid can be used to check for the presence of a magnet.

Treatment Providing a forestomach magnet, confinement and nursing care, including antibiotics, are the initial treatments. In severe cases, rumenotomy may be considered.

c. Hypocalcemia (Parturient Paresis, Milk Fever)

Etiology Hypocalcemia is an acute metabolic disease of ruminants that requires emergency treatment; the presentation is slightly different in ewes, does, and cows. High-producing, multiparous dairy cows are the most susceptible, and the Jersey breed is particularly susceptible. Cows that have survived one episode are prone to recurrence. In sheep, hypocalcemia occurs primarily in overweight ewes during the last 6 weeks of pregnancy or during the first few weeks of lactation. The disease is not as common in the dairy goat as in the dairy cow. The disease is not common in beef cattle unless there is an overall poor nutrition program.

Clinical Signs and Diagnosis In sheep, the disease is seen in ewes during the last 6 weeks of pregnancy, and is characterized by muscle tetany, incoordination, paralysis, and finally coma. Early signs in ewes include stiffness and incoordination of movements, especially in the hind limbs. Later, muscular tremors, muscular weakness, and recumbency will ensue. Morbidity may approach 30% while mortality may reach as high as 90% in untreated animals. Affected does become bloated, weak, unsteady and eventually recumbent. Cows typically are affected within 24–48 h before or after parturition. Cows initially are weak and show evidence of muscle tremors, then deteriorate to sternal recumbency, with head usually tucked to the abdomen, and an inability to stand. Muscle weakness predisposes to traumatic injuries such as splayleg or hip fractures. Tachycardia, dilated pupils, anorexia, hypothermia, depression, ruminal stasis, bloat, uterine inertia, and loss of anal tone are also seen at this stage. The terminal stage of disease is a rapid progression from coma to death. Heart rates will be high but pulse may not be detectable.

Hypocalcemia is diagnosed based on the pregnancy stage of the female and on clinical signs. It may later be confirmed by laboratory findings of low serum calcium. With hypocalcemia in ewes, the plasma concentrations of calcium drop from normal values of 8–12 mg/dl to values of 3–6 mg/dl. In cattle, plasma levels below 7.5 mg/dl are hypocalcemic.

Necropsy Findings There is no pathognomonic or typical finding at necropsy. Dairy cows which have been recumbent for more than 12 h may have severe muscle damage due to 'crush syndrome.'

Prevention and Control In sheep, maintaining appropriate body condition during the last trimester is helpful in preventing the disease. Recent information suggests that dry cow diets which rely on legume and grass forages, which are relatively high in potassium, create a slight physiological alkalosis that decreases tissue responsiveness to parathyroid hormone (Goff, 2009). Limiting sodium and potassium in the diet of prepartum cows to levels that will just meet maintenance requirements is critical. In herds with a high incidence or genetic predisposition to hypocalcemia, such as Jersey cows, increasing dietary chlorides is often helpful. Oral calcium supplements (gels or boluses) given to multiparous cows at the time of calving can be effective in preventing hypocalcemia.

Treatment Hypocalcemia must be treated quickly based on clinical signs. Pretreatment blood samples can be saved for later confirmation. Twenty percent calcium borogluconate solution should be administered by slow intravenous infusion. Solutions containing magnesium and phosphorus are also used, particularly in animals prone to relapse. Response will often be rapid with the resolution of the animal's dull mentation. Less severely affected animals will often try to stand in a short time. Relapses are common, however, in sheep and cattle. Heart rate should be monitored closely throughout calcium administration, most conveniently by palpation of the pulse in the facial artery. If an irregular (ventricular premature contractions) or rapid (ventricular tachycardia) heart rate is detected, then calcium treatment should be slowed or discontinued. Care must be taken to avoid extravascular leakage of the highly irritant calcium solution. Calcium gels and boluses available for treatment may be used as an adjunct but are not adequate for animals which have reached the stage of recumbancy.

d. Hypomagnesemic Tetany (Grass Tetany, Grass Staggers)

Unlike calcium, magnesium (Mg) is not under hormonal control, and Mg stores in bone are not readily mobilized. Maintenance of blood magnesium levels relies on the presence of adequate levels of magnesium in the diet. Hypomagnesemic tetany occurs most frequently in early lactation beef cows grazing lush pastures which are high in potassium and nitrogen. Dairy cattle, calves, ewes, and goats also may develop hypomagnesemia.

Clinical Signs Early signs include twitching of muscles and apprehension or hyperexcitability. Muscular spasms become more frequent until the cow becomes ataxic and falls to the ground. Clonic convulsions follow with bruxism and hypersalivation. Heart and respiratory rates are extremely elevated and the animal becomes hyperthermic due to muscular activity. Blood Mg levels below 1.1 mg/dl coincide with clinical signs, but CSF and vitreous humor are more reliable necropsy specimens.

Epizootiology Low magnesium concentrations in rapidly growing forages along with inadequate Mg supplementation are the primary cause. Higher concentration of potassium in these lush, immature forages interferes with absorption of Mg in the rumen. Hypocalcemia often accompanies hypomagnesemia as the lack of Mg impairs PTH secretion and activity at the target tissue (Martens and Schweigel, 2000).

Treatment and Control Treatment of hypomagnesemic convulsions is a medical emergency. Magnesium must be administered intravenously. Many solutions marketed for the treatment of hypocalcemia in dairy cows contain Mg and can be used effectively as treatment. To prevent relapse, oral drenching with Mg salts should be performed as soon as the animal has recovered enough to swallow. To prevent other cases, all other animals in the group should begin to receive Mg supplementation in the diet.

e. Ketosis (Acetonemia), Fat Cow Syndrome, Hepatic Lipidosis, Pregnancy Toxemia, Protein Energy Malnutrition

Etiology Ketosis and hepatic lipidosis are diseases of high-producing dairy cows. Pregnancy toxemia primarily is a metabolic disease of ewes and does in advanced pregnancy, particularly with twins or triplets. Beef heifers are susceptible to protein-energy malnutrition (PEM) syndrome that is also referred to as pregnancy toxemia. These metabolic disease syndromes have slightly different clinical syndromes but are all related to a negative energy balance.

Clinical Signs Clinical signs include anorexia, weakness, and lethargy. In dairy cattle, ketosis occurs in the first 6 weeks of lactation. Weight loss and thin body condition may be seen, and hypoglycemia, ketonemia, and ketonuria are evident. Some caretakers may be able to smell fruity ketones on the animal's breath. Animals with severe ketosis can exhibit neurologic signs, including circling, head-pressing, and apparent blindness. In sheep and goats, pregnancy toxemia generally occurs in the last six weeks of gestation and in ewes and does with multiple fetuses. Lactational ketosis and/or fatty liver disease can also occur during the early postpartum period in small ruminants and manifest similarly to that described for dairy cows. Hypoglycemic and/or ketotic ewes and does may begin to wander aimlessly and move away from the flock. They become anorexic and uncoordinated, frequently leaning against objects, and may display, muscle tremors, teeth grinding, convulsions, and coma. Often the animal is found unable or unwilling to rise, and up to 80% of infected ewes may die from the disease. If fetal death occurs, acute toxemia and death may result.

Pathogenesis Dairy cows normally experience a decrease in dry matter intake in the 2–3 weeks before calving. In obese cows, this drop in intake is exaggerated. Negative energy balance is a result of lower intake in conjunction with increasing nutrient demands of the growing fetus and colostrogenesis. In addition, dairy cows typically mobilize body adipose stores to support the energy demands of milk production for the first 7–8 weeks of lactation. When adipose reserves are mobilized, ketone bodies (acetone, acetoacetate, and beta-hydroxybutyrate) are produced in the liver. Although ketones are utilized by many body tissues as a source of energy, excessive levels in blood lead to ketonemia and ketoacidosis. In addition, mobilization of stored triglycerides in adipose results in increased blood nonesterified fatty acids (NEFAs). A disproportionate amount of NEFA is extracted by the liver, resulting in an accumulation of liver triglycerides which can exceed 20% of tissue dry weight.

In small ruminants and beef cattle, rapid fetal growth and/or lactational demands, a decline in maternal nutrition, or a voluntary decrease in food intake in overfat animals result in an inadequate supply of glucose needed for both maternal and fetal tissues. The animal develops a severe hypoglycemia in early stages of the disease. The oxidation of fatty acids results in the formation of ketone bodies resulting in ketoacidosis.

PEM in beef cattle occurs in late gestation or the early post-partum period, and also has a higher incidence in cows with twins, and first calf heifers. Heifer cattle have high energy requirements for completing normal body growth and supporting a pregnancy. Additional energy requirements are imposed during pregnancy, cold weather and during concurrent diseases. Marginal diets and poor-quality forage will place the cows in a negative energy balance.

Diagnosis Ketosis is diagnosed by clinical signs; sodium nitroprusside tablets or ketosis dipsticks may be used to identify ketones in the urine or plasma. In dairy cattle, blood glucose is typically less than 40 mg/dl, total blood ketones >30 mg/dl, and milk ketones >10 mg/dl. In small ruminants, blood glucose levels found to be below 25 mg/dl and ketonuria are good diagnostic indicators. Often ketones can be smelled in the cow's breath and milk. In prepartum cattle and in lactating cows, blood levels of NEFA greater than 1000 uEq/l and 325–400 uEq/l are abnormal (Gerloff and Herdt, 2009). Triglyceride analysis of liver biopsy specimens is useful.

Treatment Management of ketosis must be accompanied by a thorough physical exam to determine if concurrent disease (such as metritis or displaced abomasum) is present. Intravenous treatment with 50% glucose followed by oral supplementation with propylene glycol often produces significant clinical improvement. Glucocorticoids and/or long-acting insulin may be used as adjunct therapy (Smith, 2009). In sheep and goats, reducing glucose demand by inducing abortion or surgical removal of the offspring may be helpful. Because the morbidity in sheep may be as high as 20%, treatment should be directed at the flock rather than the individual. Treating the individual ewe often is unsuccessful.

Necropsy Findings At necropsy, small ruminants often will have multiple fetuses which may have died and decomposed. The liver will be enlarged, yellow, greasy, and friable with fatty degeneration. If severe, the liver will float in formalin or water. Beef heifers will be very thin, and in dairy cattle in addition to a fatty liver, signs of concurrent diseases may be present.

Differential Diagnoses Hypocalcemia is a common differential diagnosis. Toxemia associated with mastitis, enterotoxemia, and peritonitis should be considered. In cattle, differentials include chronic or untreated diseases such as Johne's, lymphoma, parasitism, abomasal disease, vagal indigestion, and chronic respiratory diseases.

Prevention Providing adequate nutrition and managing body weight gain in late lactation, particularly in dairy cattle with prolonged lactation or delayed breeding, helps in prevention. Dry and lactating cows should be maintained and fed separately; their energy, protein, and dry matter requirements are very different. Management of cows in the pre-partum period should focus on reducing stress and maintaining feed intakes. Providing monensin and/or rumen-protected choline in the pre-partum diet may reduce fatty infiltration of the liver. In sheep and does in late pregnancy, the dietary energy and protein should be increased 1.5- to 2-times the maintenance level.

Research Complications In research requiring pregnant animals in late stages of gestation, for example, this disease should be considered if the animals are likely to bear twins and will be transported or stressed in other ways during that time.

f. Urinary Calculi (Obstructive Urolithiasis, Water Belly)

Etiology Urolithiasis is a metabolic disease of intact and castrated male sheep, goats, and cattle characterized by the formation of bladder and urethral crystals, urethral blockage and anuria (Anderson and Rings, 2009). Male sheep and goats have a urethral process that predisposes them to entrapment of calculi. In cattle, the urethra narrows at the sigmoid flexure, and calculi lodge in the distal flexure most frequently. Additionally, the removal of testosterone by early castration is thought to result in hypoplasia of the urethra and penis. The disease is rare in female ruminants.

Clinical Signs and Diagnosis Affected animals will vocalize and begin to show signs of uneasiness, such as treading, straining postures, arched backs, raised tails, and squatting while attempting to urinate. Male cattle

may develop swelling along the ventral perineal area. Small amounts of urine may be discharged and crystal deposits may be visible attached to the preputial hairs.

In smaller ruminants, the vermiform urethral appendage (pizzle) often becomes dark purple to black in color. The pulsing pelvic urethra may be detected by manual or digital rectal palpation, and bladder distention may be noticeable in cattle by the same means. As the disease progresses to complete urethral blockage, the animal will become anorexic and show signs of abdominal pain such as kicking at the belly. The abdomen will swell as the bladder enlarges and rupture can occur within 36 h after development of clinical signs; subsequent development of uremia and hyperkalemia will eventually lead to death.

Diagnosis is made by the typical clinical signs. Abdominocentesis may yield urine. Creatinine concentration in abdominal fluid that is 1.5- to 2-fold greater than serum creatinine is diagnostic for uroperitoneum. Calculi are usually composed of calcium phosphate or ammonium phosphate matrices.

Epizootiology and Transmission Clinical disease is usually seen in growing intact or castrated males. The disease may be sporadic or there may be clusters of cases in the flock or herd.

Necropsy Findings Necropsy findings include severe hemorrhage and inflammation of the bladder wall. There may be urine in the abdomen with bladder or urethral rupture. Calculi or struvite crystal sediment will be observed in the bladder and urethra.

Differential Diagnoses Grain engorgement, colic, gastrointestinal blockage, and causes of tenemus, such as enteritis or trauma are differentials. Trauma to the urethral process should be considered.

Prevention and Control One case often is indicative of a potential problem in the group. Urolithiasis can be minimized by maintaining the calcium:phosphorus ratio in the diet at 2–2.5:1 with phosphorus levels at no more than 0.6% of diet dry matter. Increasing the amount of dietary roughage will help balance the mineral intake and increase the amount of phosphorus excreted via feces rather than urine. Increasing the amount of salt (sodium chloride, 2–4%) in the diet to increase water consumption, or adding ammonium chloride to the diet (10 g/head/day or 2% of the ration) to acidify the urine, will aid in the prevention of this disease (Anderson and Rings, 2009). Palatability of and accessibility to water should be assessed as well as functioning of automatic watering equipment.

Treatment Treatment is primarily surgical (Smith and Sherman, 2009). A lumbosacral epidural will relieve pain and facilitate examination of the penis, as will the use of acepromazine as a sedative. Initially, amputation of vermiform urethral appendage may alleviate the disease in small ruminants since urethral blockage often begins here. In more advanced stages, perineal urethrostomy may yield good results. The prognosis is poor when the condition becomes chronic, reoccurs, or surgery is required.

Research Complications Young castrated and intact male ruminants used in the lab setting will be the susceptible age group for this disorder.

3. NUTRITIONAL DISEASES

a. Copper Deficiency (Enzootic Ataxia, Swayback)

Etiology Chronic copper deficiency in pregnant ewes and does may produce a metabolic disorder in their lambs and kids called enzootic ataxia. In goats, this deficiency also causes 'swayback' in the fetuses. Enzootic ataxia is rarely seen as most North American diets have sufficient copper levels to prevent this disease. However, copper antagonists in the feed or forage may predispose to copper deficiencies. The most important of these reactions are the interaction between copper, molybdenum and sulfates.

Clinical Signs and Diagnosis This results in a progressive hind limb ataxia and apparent blindness in lambs up to about 3 months of age. Ewes may appear unthrifty, anemic and have poor quality, depigmented wool with a decrease in wool crimp. Affected kids are born weak, tremble and have the characteristic concavity to the spinal cord giving the name 'swayback.' Copper deficiency in cattle is associated with chronic diarrhea, weight loss, unthriftiness, and changes in coat color. Rarely there will be aortic aneurysms or dissections. Pathologic fractures may occur in young animals. Diagnosis is based on low copper levels found in feedstuffs and tissues at necropsy.

b. Copper Toxicosis

Etiology Acute or chronic copper ingestion or liver injury often causes a severe acute hemolytic anemia in weanling to adult sheep, and in calves and adult dairy cattle. Growing lambs may be the most susceptible. Copper toxicosis is rare in goats.

Clinical Signs and Diagnosis The clinical course in sheep can be as short as 1–4 days and mortality may reach 75%. Intravascular hemolysis, anemia, hemoglobinuria, and icterus characterize the acute hemolytic crisis, associated with copper released from the overloaded liver. Some clinical signs are related to direct irritation to the gastrointestinal tract mucosa. Weakness, vomiting, abdominal pain, bruxism, diarrhea, respiratory difficulty, and circulatory collapse are followed by recumbency and death.

Hepatic biopsy is currently considered the best diagnostic approach. Serum or plasma levels of copper and hepatic enzymes such as AST and GGT may provide some information, but it is generally believed that these will not accurately reflect total copper load or hepatic damage.

Epizootiology and Transmission A single toxic dose for sheep is in the range of 20–100 mg/kg, and for cattle is 220–880 mg/kg. Chronic poisoning in sheep may occur when 3.5 mg/kg is ingested. Copper-containing pesticides, soil additives, therapeutics, and improperly formulated feeds may potentially lead to copper toxicity. The feeding of poultry litter or forages fertilized with poultry or swine manure may also result in toxicity. A common cause of the disease in sheep is feeding concentrates balanced for cattle. Cattle feed and mineral blocks contain higher quantities of copper than are required for sheep. Chronic ingestion of these feedstuffs leads to copper accumulation and toxicity. Copper toxicosis has been reported in calves given regular oral or parenteral copper supplements, and in adult dairy cattle given copper supplements to compensate for copper deficient pasture. Pregnant dairy cattle and Jersey cattle may be more susceptible to copper toxicity. Sources of copper ingestion may include copper sulfate footbaths.

Necropsy Findings Icterus; a soft, dark, friable, enlarged spleen; an enlarged, yellow–brown friable liver; and, 'gun-barrel' black kidneys are common findings. Hemoglobin-stained urine will be visible in the bladder. Copper accumulations in the liver reaching 1000–3000 ppm are toxic.

Differential Diagnoses Other causes of hemolytic disease include babesiosis, trypanosomiasis, anaplasmosis, and plant poisonings such as kale. Arsenic ingestion, organophosphate toxicity, cyanide and nitrate poisoning should also be considered as a cause of poisoning. Urethral obstruction and gastrointestinal emergencies should be considered for the abdominal pain.

Prevention and Control The disease is prevented by carefully monitoring copper access in sheep and copper supplementation in cattle. Sheep and goats should not be fed feedstuffs formulated for cattle, and dairy calf milk replacer should not be used for lambs and kids.

Treatment Oral treatment for sheep or cattle consists of sodium molybdenate (and sodium thiosulfate orally for 3 weeks to aid in excretion of copper. Oral D-penicillamine daily for 6 days (50 mg/kg) has also been shown to increase copper excretion in sheep. Treatment for anemia and nephrosis may be necessary in severe cases.

Research Complications Breeds of sheep, such as the Merino and Merino crosses as well as British breeds, may be more susceptible to copper toxicosis caused by phytogenous sources.

c. Selenium/Vitamin E Deficiency (Nutritional Muscular Dystrophy or NMD Nutritional Myodegeneration, White Muscle Disease)

Etiology Nutritional muscular dystrophy (NMD), or stiff lamb disease, is a muscular dystrophy caused by a deficiency of selenium (Se) or vitamin E or both in young ruminants. Selenium and vitamin E function together as antioxidants that protect cell membranes from oxidative damage. Selenium is a cofactor for glutathione peroxidase which converts hydrogen peroxide to water and other nontoxic compounds. Lack of one or both nutrients results in loss of membrane integrity.

Clinical Signs and Diagnosis Clinically two forms of the disease have been identified: cardiac and skeletal. The cardiac form occurs most commonly in neonates and typically has a rapid onset; animals may be found severely debilitated or dead. Respiratory difficulty will be a manifestation of damage to cardiac, diaphragmatic, and intercostal muscles. In older animals, locomotor disturbances and/or circulatory failure may accompany respiratory signs. Clinically, animals may display paresis, stiffness or inability to stand, rapid but weak pulse, and acute death. Mortality may reach 70% (Hefnawy and Totura-Perez, 2010). Paresis and sudden deaths in neonates with associated pathological signs are frequently diagnostic. With the skeletal form, affected animals are stiff and reluctant to move and muscles of affected animals are painful. Young will be reluctant to get up, and may have difficulty nursing (dysphagia). Subclinical disease results in subtle immune defects.

Diagnosis Definitive diagnosis is based on determination of whole blood levels of Se (>0.07 ppm Se is normal) and plasma levels of vitamin E (<1.1 ppm). Glutathione peroxidase levels in red blood cells can be measured as an indirect test.

Epizootiology and Transmission Se deficiency and NMD occurs in young, rapidly growing calves, lambs, and kids. Se-deficient soils are common in many areas of the United States (including the Northeast, Northwest, and Great Lakes regions) and throughout the world. Diets based on feeds grown in these areas will result in Se deficiency if the mineral is not supplemented. The U.S. Food and Drug Administration limits supplemental Se in complete ruminant diets to 0.3 ppm (no more than 0.7 mg/day for adult sheep and 3 mg/day for adult cattle). This level of supplementation often is not adequate in deficient areas and the use of injectable sources is necessary to prevent clinical deficiencies.

Necropsy Findings Necropsy lesions include petechial hemorrhages and muscle edema. Hallmarks are pale-white streaking of affected skeletal and cardiac muscle, diaphragm, and tongue. However, muscles of young ruminants are normally very pale, and lesions may not be readily visible without histologic examination.

Differential Diagnoses In neonatal ruminants presenting with respiratory and cardiac dysfunction, differentials include congenital cardiac anomalies and pneumonia.

Prevention and Control Awareness of regional selenium deficiencies is important as disease is frequently subclinical. Control involves vitamin E and selenium

supplementation, particularly to pregnant dams and/or young animals in deficient areas. Injectable selenium supplements are required to prevent clinical disease in severely deficient regions.

Treatment Affected animals may be treated by administering vitamin E and selenium injections.

d. Selenium Toxicity

Selenium toxicity occurs most frequently as the result of excessive dosing to prevent or correct selenium deficiency, feed manufacturing errors, or following ingestion of Se-concentrating plants. The main preventative measure for the former is the use of the appropriate supplement or injectable product for the species being treated. In the United States, ruminants on arid alkaline soils (found primarily in the western states) may be subject to selenium toxicity especially when pastured in areas containing Se-accumulating plants. Signs of selenosis include weakness, dyspnea, bloating, and diarrhea. Shock, paresis, and death may occur. Initial clinical signs of excessive selenium intake from plants are observed in the distal limb with cracked hoof walls and subsequent infection and irregular hoof growth.

e. Thiamine Deficiency/Polioencephalomalacia

Etiology Polioencephalomalacia (PEM) is a noninfectious, nutritional disease characterized by neurological signs. PEM is caused by thiamine deficiency due to inadequate ruminal thiamine production or bacterial thiaminase production in cattle and sheep consuming diets high in fermentable carbohydrates. Animals exposed to toxic plants (bracken fern or equisetum), moldy feed containing thiaminases, or to feed or water high in sulfates also are at risk. The condition occurs throughout the world and affects cattle, sheep, goats, deer, and camelids.

Clinical Signs and Diagnosis Early clinical signs include anorexia, ataxia and/or hypermetria, bruxism, hypersalivation, hyperesthesia, and muscle tremors. As the disease progresses, cortical blindness, head-pressing, head tilt, opisthotonus, nystagmus, dorsalmedial strabismus, seizures, and death ensue. Body temperatures are normal unless excessive muscle activity has resulted in hyperthermia and ocular reflexes are normal. Morbidity and mortality may be high especially in younger animals. Diagnosis is suggestive from clinical signs, and response to intensive parental thiamine hydrochloride.

Necropsy Signs Cerebral lesions characterized by softening and discoloration are grossly observed in the gray matter. Microscopically, neurons will exhibit edema, chromatolysis, and shrinkage.

Differential Diagnoses Several important differentials include acute lead poisoning, hypomagnesemia, listeriosis, rabies, pregnancy toxemia, infectious thromboembolic meningoencephalitis, and type D clostridial enterotoxemia.

Prevention and Control The disease can be prevented by monitoring the diet and by providing adequate roughage necessary to support ruminal production of B vitamins. If excess sulfates are the primary factor, then immediate removal of the source is critical.

Treatment Early aggressive treatment is essential to save animals. The disease is treated by frequent parenteral administration of thiamine hydrochloride, the first dose being administered intravenously. Dexamethasone, B vitamins, and diazepam may also be required.

Research Complications This is a preventable disease. Although less likely to occur in smaller groups of confined ruminants, the risks of feeding concentrates or moldy feed, for example, with minimal good quality roughage, should be kept in mind.

f. Salt Toxicity

Salt poisoning may result from the practice of feeding high-salt supplements to restrict intake, from consuming water that is high in sodium, from mistakes in formulation or preparation of feedstuffs or electrolyte solutions, and from the feeding of high-sodium byproducts (whey, waste food products). Restriction of water also may result in sodium toxicity.

Clinical Signs Clinical signs of sodium toxicity include colic and diarrhea, blindnesss or 'star-gazing,' hyperexcitability, head-pressing, ataxia, incessant chewing, nystagmus, and seizures progressing to coma and death. Sodium levels will be elevated in serum and CSF. Animals allowed to rehydrate rapidly may develop intravascular hemolysis and hemoglobinuria. Cerebral edema may be present on necropsy (Fecteau and George, 2009).

Treatment and Control Affected animals should receive normal or hypertonic saline intravenously followed by oral fluid replacement. Mannitol (0.5–1 g/kg) may be useful in the treatment of calves and small ruminants. Prognosis is poor for animals with severe neurologic clinical signs. Control relies on providing adequate amounts of fresh water (<7000 ppm sodium), and in particular avoiding water restriction if high-sodium feeds are used. Oral electrolyte solutions for young ruminants must always be prepared according to manufacturers' instructions.

4. MANAGEMENT-RELATED

a. Failure of Passive Transfer

Because of their epitheliochorial placentation, neonatal ruminants are born without immunoglobulins and must receive colostrum as soon as possible after birth. The morbidity and mortality associated with inadequate passive transfer of antibodies in colostrum can be severe.

Measures to ensure passive immunity for neonatal ruminants are covered under management, and clinical signs of illness associated with lack of immunity are addressed under bacterial diseases, such as *E. coli*, and viral diseases, such as diarrheas. Generally, failure of passive transfer is defined by serum concentration of less than 10 mg/ml IgG1 at 48 h after birth. Methods to determine success of transfer should be performed within a week of birth and include: single radial immunodiffusion (quantitates immunogloblin classes), ELISA test kits (available commercially), zinc sulfate turbidity (semiquantitative), sodium sulfite precipitation (semiquantitative), glutaraldehyde coagulation (coagulates above specific level), and serum gamma-glutamyltransferase activity (assays enzyme in high concentration in colostrum and absorbed simultaneously with colostrum). Total serum protein of greater than 5 g/dl measured by refractometer has been associated with adequate immunoglobulin concentrations in hydrated animals.

b. Laminitis (Subsolar Abscesses, White Line Disease)

Laminitis is common in ruminants, particularly in dairy cattle. Laminitis is often a sequel of acute or subacute ruminal acidosis (covered above) caused by sudden changes in diet or by diets containing excessive amounts of nonstructural carbohydrate (starch and sugars) and inadequate fiber. Laminitis also may be associated with febrile episodes such as mastitis, metritis, or respiratory disease. Facility conditions, such as concrete flooring and inadequate resting areas, may also contribute to the pathogenesis of laminitis. Abrupt changes in diet cause changes in rumen microbial populations resulting in acute or subacute ruminal acidosis and endotoxemia. Alterations in the vascular endothelium result in chronic inflammation of the sensitive laminae of the hoof, separation of corium and hoof wall, and rotation of the third phalanx.

Rotation of the third phalanx associated with laminitis frequently leads to subsolar abscesses. These abscesses commonly occur in toe or heel region of the sole due to pressure on the solar corium. Solar abscesses may progress to full-thickness defects in the sole with attendant infection. These animals are severely lame, reluctant to move, and subsequently lose body weight and production.

Diagnosis Affected animals may be reluctant to get up or walk, will shift their weight frequently, and will grind teeth or walk on carpi. Rotation of the third phalanx can result in paint-brush hemorrhages in the hoof sole and eventually sole abscesses. Chronically, the hoof wall takes on a 'slipper' appearance. Treatment consists of identifying and correcting the underlying cause, administering anti-inflammatories (flunixin meglumine) and regular foot trimming. Proper diet formulation, preparation, and delivery are crucial. Sole abscesses can be treated with trimming and bandaging. The cow's comfort and mobility can often be restored by gluing a wooden block or slipper onto the healthy claw in order to remove the weight burden from the claw with the abscess (Van Amstel, 2009).

c. Hemorrhagic Bowel Syndrome (Jejunal Hemorrhage Syndrome)

Hemorrhagic bowel syndrome (HBS) is an acute enteric disease, primarily affecting dairy cows in the first three to 3–4 four months of lactation. HBS was first reported in the 1990s but appears to be increasing in prevalence (NAHMS Dairy Studies, 2007). The disease can strike very rapidly and, at times, previously healthy cows are simply found dead. The notable lesion is hemorrhage into a segment of the small intestine, resulting in a blood clot which produces a functional obstruction. Depending on the rate and volume of the hemorrhage, some cattle may present in hypovolemic shock, with elevated heart rate, weak pulse, pale mucous membranes, and cold extremities. Cases with slower progression may present with abdominal distension, anorexia, fluid splashing sounds, or localized 'pings' in the lower right abdomen. Feces may be normal or tarry-colored or contain clotted blood. Most cases develop fatal septic shock within 24–48 h due to necrosis of the intestinal wall. The case fatality rate is reported to be 80–100%.

The etiology of HBS is not well-understood and is likely to be multifactorial. Many authors implicate *Clostridium perfringens* type A, but *Aspergillus fumigatus* also may play a role in the pathogenesis. The disease is associated with larger and higher-producing dairy herds and with energy-dense diets which have relatively low fiber levels.

On necropsy, purple or red discolored segments of small intestine will be identified. The intestinal contents may be mixed with unclotted blood, or firm blood clots may be tightly adhered to the mucosa (Van Metre, 2009).

Treatment for HBS usually is unsuccessful. Medical treatment with fluids, laxatives, anti-inflammatory agents, and antibiotics typically only prolongs the course of the disease. If the affected area(s) of bowel can be identified by laparotomy, the obstructed area may be relieved by gentle massage or the area of bowel may be resected.

d. Nutritional Diarrhea

In a laboratory setting, young ruminants should consume high-quality milk replacers which rely primarily on dairy products for their protein sources. Milk replacers should be mixed according to directions and fed at a consistent time and temperature. Although 'overfeeding' is often blamed for diarrhea in calves, there is no

research to support this. Calves with *ad libitum* access to milk may consume up to 20% of their body weight in milk daily without developing diarrhea. However, poor-quality milk replacers and inconsistent preparation and presentation of milk replacers may exacerbate diarrhea due to enteric pathogens.

e. Photosensitization (Bighead)

Photosensitization is an acute dermatitis associated with an interaction between photosensitive chemicals and sunlight. Photosensitive chemicals are usually ingested but in some cases exposure may be by contact. Animals with a lack of pigment are more susceptible to the disease. Three types of photosensitization occur: primary, secondary or hepatogenous, and aberrant. Primary photosensitization is related to plant pigments or drugs such as phenothiazine, sulfonamides, or tetracyclines. Secondary photosensitization is more common in large animals, and is specifically related to the plant pigment phylloerythrin. Phylloerythrin, a porphyrin compound, is a degradation product of chlorophyll released by rumen microbial digestion. Liver disease or injury, which prevents normal conjugation of phylloerythrin and excretion through the biliary system, predisposes to photosensitization. The only example of aberrant photosensitization is congenital porphyria of cattle (see Section III, B, 1).

Pathologically, the photosensitive chemical is deposited in the skin and is activated by absorbed sunlight. The activated pigments convert local amino acids and proteins to vasoactive substances which increase the permeability of capillaries leading to fluid and plasma protein losses and eventually local tissue necrosis. Photosensitization can occur within hours to days after sun exposure and produces lesions of the face, vulva, and coronary bands. Lesions are most likely to occur on white-haired or thinly haired areas. Initially, edema of the lips, corneas, eyelids, nasal planum, face, vulva, or coronary bands occurs. Facial edema, nostril constriction, and swollen lips potentially lead to difficulty breathing. With secondary photosensitization, icterus is also common. Necrosis and gangrene may occur. Diagnosis is based on clinical lesions and exposure to the photosensitive chemicals and sunlight. Treatment is symptomatic.

f. Reproductive (Vaginal, Uterine) Prolapses

Vaginal and uterine prolapses occur in ewes and cows and less commonly in does. Vaginal prolapses usually occur during late gestation and may be related to relaxation of the pelvic ligaments in response to hormone levels. In sheep, these are most common in overconditioned ewes that are also carrying twins or triplets.

The condition may result from excessive straining associated with dysuria from the pressure of the fetuses and/or abdominal contents on the bladder. If the prolapse obstructs subsequent urination, rupture of the bladder may occur. The vaginal prolapse can be reduced and repaired if discovered early. Techniques for replacement in small and large ruminants are comparable. The animal should be restrained and the prolapsed tissue should be cleansed with disinfectants. Best done under epidural anesthesia, the vagina is replaced into the pelvic canal and the vulvar or vestibular opening is sutured closed (Buhner suture). Alternatively, a commercial device called a bearing retainer (or truss) can be placed into the reduced vagina and tied to the wool, thereby holding the vagina in proper orientation without interfering with subsequent lambing.

Vaginal prolapses may have a hereditary basis in ewes and cows and may recur the following year. These animals should be culled. Vaginal prolapses may occur in nonpregnant animals grazing estrogenic plants or as sequelae to docking the tail too close to the body (Ross, 1989).

Uterine prolapses occur sporadically in postpartum ewes and cattle. The gravid horn invaginates after delivery and protrudes from the vulva. The cause is unknown, but excessive traction utilized to correct dystocia or retained placenta, uterine atony, hypocalcemia and overconditioning or lack of exercise have been implicated. In cattle, the uterine prolapses usually develop within 24 h of calving, are more common in dairy than beef cows, and are often associated with dystocia or hypocalcemia. Cows may also have concurrent parturient paresis. Initially, the tissue will appear normal, but edema and environmental contamination or injuries of the tissue develop quickly. The weight of the prolapsed uterus can potentially tear the mesometrial arteries resulting in fatal hemorrhage.

Clinical signs will include increased pulse and respiratory rates, straining, restlessness, and anorexia. If identified early, the uterus can be replaced as for vaginal prolapses, taking care to avoid trauma to the exposed endometrium. Electrolyte imbalances (particularly hypocalcemia) should be corrected if present. Passively infusing several gallons of warm fluid into the uterus following reduction will aid in completely inverting the uterine horns. Additional supportive therapy including the use of antibiotics should always be considered. Tetanus prophylaxis should be included. Oxytocin should be administered to induce uterine involution, but only after the uterus has been replaced. Vaginal closures are less successful at retaining uterine prolapses. Preventative and control measures include regular exercise for breeding animals, prevention of hypocalcemia and management of body condition in cows and ewes.

g. Rectal Prolapse

Rectal prolapses are common in growing, weaned lambs and cattle from 6 months to 2 years old. The

physical eversion of the rectum through the anal sphincter is usually secondary to other diseases or management-related circumstances. Rectal prolapses may occur secondary to gastrointestinal infection or inflammation, especially when the colon is involved. Diseases such as coccidiosis, salmonellosis, and intestinal parasites that cause tenesmus may result in prolapse. Urolithiasis may result in rectal prolapses as the animal strains to urinate. Any form of cystitis or urethritis, vaginal irritation or vaginal prolapse, and some forms of hepatic disease may lead to rectal prolapses. Abdominal enlargement related to advanced stages of pregnancy, excessive rumen filling or bloat, and overconditioning may cause prolapses as can coughing during respiratory tract infections, or improper tail docking (too short).

Diagnosis is based on clinical signs. Early prolapses may be corrected by holding the animal with the head down, while a colleague places a purse-string suture around the anus. The mucosa and underlying tissue of prolapses that have been present for longer periods of time will often become necrotic, dry, friable, and devitalized and will require surgical amputation or the placement of prolapse rings to remove the tissue. Rectal prolapses may also be accompanied by intestinal intussusceptions that will further complicate the treatment and increase mortality. Occasionally, acute rectal prolapses with evisceration will result in shock and prompt death of the animal. Prognosis depends on the cause, extent of the prolapse as well as timeliness of intervention. In all cases, determination and elimination of the underlying cause is essential.

h. Trichobezoars, Phytobezoars, and Enteroliths

Gastrointestinal accumulations or obstructions of hair, indigestible plant material or other foreign material can occur in cattle and sheep. Cattle that are maintained on a low-roughage diet, that lick their coats frequently, that have long hair coats from outdoor housing, or that have heavy lice or mite infestations, will often develop trichobezoars. In addition, younger calves with abomasal ulcers have been found to more likely to also have abomasal trichobezoars. Enteroliths also can form from indigestible material that the animals have consumed (e.g., plastic bale twine or sheeting).

Clinical signs may be mild or severe according to size, number, and location. Ruminal trichobezoars rarely result in clinical signs. Obstruction will be accompanied by signs of pain, development of bloat, and decreased appetite and fecal production. Diagnosis is based on abdominal auscultation, rectal palpation, and ultrasound (useful in calves and smaller ruminants). Treatment is surgical, such as paracostal laparotomy (for abomasal), rumenotomy, or right paralumbar celiotomy (for obstruction of the duodenum, jejunum, or spiral colon). Supportive care should be administered as necessary to correct electrolyte imbalances and prevent inflammation and sepsis. Prognosis is generally good if the condition is diagnosed and treated before dehydration and imbalances become severe and peritonitis develops. Prevention includes good-quality roughage, treating lice and mange infestations, and avoiding incorporation of plastic materials into mixed rations.

C. Traumatic

1. Wounds, Bites, Entrapped Foreign Bodies

Wounds may be sustained from poorly constructed facilities or from skirmishes among animals. Predators will usually be sources of bite wounds, and the potential for rabies exposure should be considered. Frontal sinusitis is a potential complication of dehorning older ruminants. Standard veterinary wound assessment and care are essential for wounds or bites. Tetanus antitoxin may be indicated. Use of approved antibiotics may be appropriate. Wounds should be cleaned with disinfectants and repaired with primary closure if clean and uncontaminated. Thorough cleaning and regular monitoring and healing by second intention are recommended for older wounds. Abscesses may also occur in the soft tissues of the hooves due to entrapped foreign bodies or hoof cracks filling with dirt. Paraphimosis may be seen in male ruminants associated with hair rings around the penis. Preventative measures include improvement of housing facilities, pens, and pastures; monitoring hierarchies among animals penned together; and implementing predator control measures, such as sound fencing or flock guard dogs or donkeys in pasture situations. Seasonal fly control to avoid maggot infestation of wounds must be considered.

D. Iatrogenic

1. Anaphylactic Reactions

Acute anaphylactic reactions in sheep, goats and cattle are often clinically referable to the respiratory system. The lung is the major target organ in cattle for Type 1 hypersensitivity. Anaphylactic vaccine reactions cause acute lung edema; lungs are the primary site of lesions if collapse and death are sequelae. The animals will also be anxious, shivering and become hyperthermic. Salivation, diarrhea, and bloat also occur. Immediate therapy must include epinephrine (1 ml of 1:1000 per 50 kg body weight for goats; 1:10,000 [0.1 mg/ml], 0.01 mg/kg [about 5 ml], for adult cow) by intravenous infusion. Treatment should also include anti-inflammatories such as corticosteroids (dexamethasone, 5–20 mg IV) or NSAID's. Furosemide (5 mg/kg) may be beneficial to reduce edema. Tracheostomy may be indicated if pharyngeal or laryngeal edema is present. Prognosis is usually guarded. Recovery can occur within 2 h.

2. *Catheter Sites, Experimental Surgeries*

In a research environment, catheter sites or experimental surgeries may be sources of iatrogenic infection. Traumatic injuries to peripheral nerves or improper injection of pharmaceuticals can cause acute lameness. Contraction of the quadriceps results in the limb being pulled forward. Traumatic injury to the radial nerve can result in a 'dropped elbow.' Husbandry procedures such as tail docking, castration, dehorning, dosing with a balling gun, and shearing may result in superficial lesions, dermal infections, or cases of tetanus. Balling gun injuries to the pharynx may lead to cellulitis with coughing, decreased appetite and sensitivity to palpation.

Standard veterinary assessment and care are essential for these cases. Local and systemic antibiotics with supportive care may be indicated. Swelling around peripheral nerves caused by inoculations may be reduced by diuretics and anti-inflammatories. Mild cases of peripheral nerve damage may recover in 7–14 days. Personnel training, including review of relevant anatomy, preprocedure preparation, appropriate technique, careful surgical site preparation, rigorous instrument sanitation, and sterile technique will minimize the incidence of potential complications from surgical procedures. Lastly, appropriate facilities and equipment kept in good repair will facilitate safe and effective restraint of large animals and help reduce incidence of these types of iatrogenic conditions.

E. Neoplastic

Neoplasia and tumors are relatively rare in ruminants. Lymphoma/leukemia in sheep has been shown to result from infection by a virus related (or identical) to the bovine leukemia virus. Pulmonary carcinoma (pulmonary adenomatosis) and hepatic tumors are found in sheep. Pulmonary adenosarcoma in sheep, described previously, is a transmissible viral disease. Also, virus-induced papillomatosis as discussed earlier, and squamous cell carcinomas have also been reported in sheep.

In goats, thymoma is one of the two most common neoplasias reported, although no distinct clinical syndrome has been described. Cutaneous papillomas are the most common skin and udder tumor of goats, and although outbreaks involve multiple animals, no wart virus has been identified. Persistent udder papillomas may progress to squamous cell carcinoma. Lymphoma is reported rarely in goats.

Lymphoma of various organ systems and 'cancer eye' (bovine ocular squamous cell carcinoma, BSCC) are the most commonly reported cancers in cattle. Lymphoma is described above under Bovine Leukemia Virus (Section III, B, 2, a, ii). Lack of periocular pigmentation, amount and intensity of exposure to solar ultraviolet light, and age are considered important factors in BSCC. Genetic factors may also play a role as many cases occur in Herefords. The cancer metastasizes through the lymph system to major organs. Treatment in either lymphoma or BSCC is recommended only as a palliative measure, although enucleation may be successful if the disease is still localized. The extent of ocular neoplastic involvement is a significant criterion for carcass condemnation. Papillomatosis (warts) is common in cattle, and the disease is described under viruses.

Forms of bovine lymphoma that are not associated with BLV infection are calf or juvenile; thymic or adolescent (animals 6 month to 2 years); and cutaneous (any age). The calf form is rare and characterized by generalized lymphadenopathy. Onset may be sudden, and the disease is usually fatal within a few weeks. Signs include lymphadenopathy, anemia, weight loss, and weakness. Some animals may be paralyzed due to spinal cord compression from subperiosteal infiltration of neoplastic cells. The adolescent form is also rare, the course rapid, and the prognosis poor. The disease is seen most often in beef breeds such as Hereford cattle and is characterized by space occupying masses in the neck or thorax. Secondary effects of the masses are loss of condition, dysphagia, and rumen tympany. The cutaneous presentation has a longer course that may wax and wane. Masses will be found at the anus, vulva, escutcheon, shoulder, and flank; they will be painful when palpated, will be raised and often ulcerated. The animals will be anemic, and neoplastic involvement may affect cardiac function. Generalized or limited lymphadenopathy may be apparent.

F. Miscellaneous

1. *Amyloidosis*

Amyloidosis in adult cattle is due to accumulations of amyloid protein in the kidney, liver, adrenal glands, and gastrointestinal tract. The disease is associated with chronic inflammatory disease, although other unknown factors are believed to be involved in some cases. Clinical signs include chronic diarrhea, weight loss, and nonpainful renomegaly and generalized edema. The loss of protein in the urine contributes to abnormal plasma albumin values and foaming urine. The proteinuria also distinguishes amyloidosis (and glomerulonephritis) from other causes of weight loss and diarrhea in cattle such as Johne's disease or parasitism. The diffuse nature and insidious onset make amyloidosis difficult to diagnose. Prognosis is poor and no treatment is reported.

2. *Dental Wear*

Ruminants have an intermandibular space that is narrower than the intermaxillary space. Dental wear is seen most commonly in sheep. As sheep age, excessive dental

wear may lead to an inability to properly masticate feed, manifesting as weight loss and unthriftiness. Dietary contamination with silica (i.e., hays, grains harvested in sandy regions) will lead to mechanical wear on the teeth. Likewise, animals grazing or being fed in sandy environments will have excessive teeth wear. Sheep older than about 5 years of age are especially prone to teeth wear and should be checked frequently; especially if signs of weight loss or malnutrition are evident. Managing the content and consistency of the diets can best prevent the disease.

References

Major References Cited Addressing Husbandry, Management, and Clinical Medicine

American Veterinary Medical Association. <https://www.avma.org/KB/Resources/FAQs/Pages/ELDU-and-AMDUCA-FAQs.aspx>.

Anderson, D.E., Rings, M., 2009. Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders Elsevier, St. Louis, MO.

Code of Federal Regulations (CFR), 1985. Title 9 (Animals and Animal Products), Subchapter A (Animal Welfare). Office of the Federal Register, Washington, DC, Public Law, 89–544.

Davis, C.L., Drackley, J.M., 1998. The Development, Nutrition and Management of the Young Calf. Iowa State University Press, Ames, IA.

Federation of Animal Science Societies (FASS), 2010. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, third ed. FASS, Savoy. Champaign, IL.

Grandin, T., 2007. Livestock Handling and Transport, third ed. CAB International, United Kingdom.

Hafez, E.S.E., Hafez, B., 2000. Reproduction in Farm Animals, seventh ed. Lippincott, Williams & Wilkins, Philadelphia, PA.

Hawk, C.T., Leary, S.L., 2005. Formulary for Laboratory Animals, third ed. Iowa State University Press, Ames, IA.

Houpt, K.A., 2010. Domestic Animal Behavior for Veterinarians and Animal Scientists, fifth ed. Wiley-Blackwell, Ames, IA.

Jurgens, M.H., Bregendahl, K., Coverdale, J., Hansen, S., 2013. Animal Feeding and Nutrition, eleventh ed. Kendall/Hunt Publishing Co., Iowa.

Kaneko, J.J., Harvey, J.W., Bruss, M.L., 1997. Clinical Biochemistry of Domestic Animals. Academic Press, San Diego, CA.

Kimberling, C.V., 1988. Jenson and Swift's Diseases of Sheep. Lea & Febiger.

Merck Veterinary Manual Online, 2011. Merk and Co. <www.merck-vetmanual.com>.

National Research Council, 2000. Nutrient Requirements of Beef Cattle, seventh Revised ed. National Academy Press, Washington, DC, Update 2000.

National Research Council, 2001. Nutrient Requirements of Dairy Cattle, seventh Revised ed. National Academy Press, Washington, DC, Update.

National Research Council, 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. National Academy Press, Washington, DC.

National Research Council, 2011. Guide for the Care and Use of Laboratory Animals, eighth ed. National Academy Press, Washington, DC.

Plumb, D.C., 2011. Veterinary Drug Handbook, seventh ed. Iowa State University Press, Ames, IA.

Pugh, D.G., Baird, A.N., 2012. Sheep and Goat Medicine, second ed. Elsevier Saunders, Maryland Heights, MO.

Radostits, O.M., Gay, C.C., Hinchliff, K.W., Constable, P.D., 2007. Veterinary Medicine: A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs and Goats, tenth ed. WB Saunders, NY, ISBN 978-0702-07772.

Reece, W.O., 2004. Duke's Physiology of Domestic Animals, twelvth ed. Cornell University Press, Ithaca, NY.

Ross, C.V., 1989. Sheep Production and Management. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Smith, B.P., 2009. Large Animal Internal Medicine, fourth ed. Mosby Elsevier, St. Louis, MO, ISBN 978-0-323-04297-0.

Smith, M.C., Sherman, D.M., 2009. Goat Medicine, second ed. Wiley-Blackwell, Ames, IA.

United States Department of Agriculture (USDA). March 25, 2011. Animal and Plant Health Inspection Service (APHIS), Policy #Farm17, Regulation of Agricultural Animals. Available at: <http://www.aphis.usda.gov/animal_welfare/policy.php?policy=17>.

Weiss, D.J., Wardrop, K.J., 2010. Schalm's Veterinarinay Hematology. Wiley-Blackwell, Hoboken, NJ.

Youngquist, R.S., Threlfall, W.R., 2007. Current Therapy in Large Animal Theriogenology, second ed. Saunders Elsevier, St. Louis, MO.

Additional References Cited or Used in the Preparation of this Chapter

21 CFR 530 1994. Animal Medicinal Drug Use Clarification Act (AMDUCA) <http://www.fda.gov/AnimalVeterinary/GuidanceComplianceEnforcement/ActsRulesRegulations/ucm085377.htm> (accessed 4.23.15).

A Guide to the National Scrapie Eradication Program for Veterinarians, 2009. <http://www.eradicatescrapie.org/Educational%20Resources/Vet%20Guide.html> (accessed 3.08.13).

American Veterinary Medical Association (AVMA) Backgrounders, 2012. <https://www.avma.org/kb/resources/backgrounders/pages/default.aspx> (accessed 3.08.13).

Armed Forces Institute of Pathology (AFIP), 1995. Animal Models of Human Disease. Registry of Comparative Pathology, Washington, DC.

Barr, B.C., Dubey, J.P., Lindsay, D.S., Reynolds, J.P., Wells, S.J., 1998. Neosporosis: its prevalence and economic impact. Suppl. Comp. Cont. Ed. Prac. Vet. 20 11(D).

Blackwell, T.E., Butler, D.G., 1992. Clinical signs, treatment, and post-mortem lesions in dairy goats with enterotoxemia: 13 cases (1979–1982). J. Amer. Vet. Med. Assoc. 200 (2), 214–217.

Bretzlaff, K., Haenlein, G., Huston, E., 1991. The goat industry: feeding for optimal production. In: Naylor, J.M., Ralston, S.L. (Eds.), Large Animal Clinical Nutrition Mosby, St. Louis, MO.

Broad, T.E., Hill, D.F., Maddox, J.F., Montgomery, G.W., Nicholas, F.W., 1998. The sheep gene map. In comparative gene mapping. ILAR J. 39, 160–170.

Brujeni, G.N., Jani, S.S., Alidadi, N., Tabatabaei, S., Sharif, H., Mohri, M., 2010. Passive immune transfer in fat-tailed sheep: evaluation with different methods. Small Ruminant Res. 90, 146–149.

Bulgin, M.S., 1986. Diagnosis of lameness in sheep. Comp. Cont. Educ. Pract. Vet. 8, F122–F128.

Center for Food Security and Public Safety, 2005. <www.cfsph.iastate.edu/Factsheets/.../nontyphoidal_salmonellosis.pdf> (accessed 3.08.13).

Center for Food Security and Public Health, 2008. Bovine Babesiosis. Iowa State University, Ames, IA, http://www.cfsph.iastate.edu/Factsheets/pdfs/bovine_babesiosis.pdf.

Cibelli, J.B., Stice, S.L., Golueke, P.J., et al., 1998a. Cloned transgenic calves produced from nonquiescent fibroblasts. Science 280, 1256–1258.

Cibelli, J.B., Stice, S.L., Golueke, P.J., et al., 1998b. Transgenic bovine chimeric offspring produced from somatic cell-derived stem-like cells. Nat. Biotechnol. 16, 642–646.

Corbeil, L.B., 1995. Use of an animal model of trichomoniasis as a basis for understanding this disease in women. Clin. Infect. Dis. 21 (Suppl. 2), S158–S161.

Cornell Animal Health Diagnostic Center. <http://ahdc.vet.cornell.edu/clinpath/modules/coags/typeoth.htm> (accessed 3.08.13).

Council Report: Vaccination guidelines for small ruminants (sheep, goats, llamas, domestic deer, and wapiti), 1994. J. Am. Vet. Med. Assoc. 205, 1539–1544.

de la Concha Bermejillo, A., 1997. Maedi-Visna and ovine progressive pneumonia. Vet. Cin. North Am. Food Anim. Pract. 13, 13–33. (Abstract).

Dorella, F.A., Pacheco, L.G., Oliviera, S.C., Miyoshi, A., Azevedo, V., 2006. Corynebacterium pseudotuberculosis: microbiology, biochemical properties, pathogenesis and molecular studies of virulence. Vet. Res. 37 (2), 201–218. review.

Dorchies, P., Duranton, C., Jacquiet, P., 1998. Pathophysiology of oestrous ovis infection in sheep and goats: a review. Vet. Rec 142 (18), 487–489. Review.

Dougherty, R.W., 1981. Experimental Surgery in Farm Animals. Iowa State University Press, Ames, IA.

Dubey, J.P., 2005. Neosporosis in cattle. Vet. Clin. North Am. Food Anim. Pract. 21, 473–483.

Easley, N.E., Wang, M., McGrady, L.M., Toth, J.M., 2008. Biomechanical and radiographic evaluation of an ovine model for the human lumbar spine. Proc. Inst. Mech. Eng. Part H J. Eng. Med. 22 (6), 915–922.

Elsik, C.G., Tellam, R.L., Worley, K.C., 2009. The genome sequence of taurine cattle: a windo to ruminant biology and evolution. The bovine genome sequencing and analysis consortium. Science 324 (5926), 522–528.

Endsley, J.J., Roth, J.A., Ridpath, J., Neill, J., 2003. Maternal antibody blocks humoral but not T cell responses to BVDV. Biologicals 31 (2), 123–125.

Fecteau, G., George, L.W., 2009. Mentation abnormality, depression, and cortical blindness. In: Anderson, D.E., Rings, M. (Eds.), Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders-Elsevier, St. Louis, MO, pp. 301–311.

Fecteau, M.E., Whitlock, R.H., 2009. Abomasal ulcers. In: Anderson, D.E., Rings, M. (Eds.), Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders-Elsevier, St. Louis, MO.

Franz-Werner, S., Maddox, J., Ballingall, K., et al., 1996. The ovine major histocompatibility complex. In: Schook, L.B., Lamont, S.J. (Eds.), The Major Histocompatibility Complex Region of Domestic Animal Species CRC Press, Inc., Taylor and Francis Group, Boca Raton, FL.

Gao, J., Liu, K., Liu, H., et al., 2010. A complete DNA sequence map of the ovine Major histocompatibility complex. BMC Genomics 11, 466.

Garrigliany, M.M., Bayrou, C., Kleijnen, D., et al., 2012. Schmallenberg virus: a new shamonda/sathuperi-like virus on the rise in Europe. Antiviral Res. 95 (2), 82–87.

Geishauser, T., Leslie, K., Duffield, T., 2000. Metabolic aspects in the etiology of displaced abomasum. Metabolic disorders of ruminants. Vet. Clin. North Am. Food Anim. Pract. 16 (2), 255–265. WB Saunders, Philadelphia, PA.

Gerloff, B.J., Herdt, T.H., 2009. Fatty liver in dairy cattle. In: Anderson, D.E., Rings, M. (Eds.), Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders Elsevier, St. Louis, MO, pp. 146–149.

Gibbs, R.A., Taylor, J.F., Van Tassell, C.P., et al., 2009. Genome-wide survey of SNP variation uncovers the genetic structure of cattle breeds. Science (New York, NY) 324 (5926), 528–532.

Goff, J.P., 2006. Major advances in our understanding of nutritional influences of bovine health. J. Dairy Sci. 89 (4), 1292–1301.

Griffiths, D.J., Martineau, H.M., Cousens, C., 2010. Pathology and pathogenesis of ovine pulmonary adenosarcoma. J. Comp. Path. 142 (4), 260–283.

Hays, J.T., Suckow, M.A., Jackson, G.E., Douglas, F.E., 1998. Considerations in the design and construction of facilities for farm species. Lab. Anim. 27 (6), 22–25.

Heaton, M., Leymaster, K., 2012. Research on Genetic Susceptibility to Ovine Progressive Pneumonia at the USDA Meat Animal Research Center (USMARC). Clay Center, Nebraska, OPP Handout. www.ars.usda.gov.

Hefnawy, A.E.G., Totura-Perez, J.L., 2010. The importance of selenium and the effects of its deficiency in animal health. Small Rum. Res. 89, 185–192.

Herfat, M.T., 2005. Characterizing the Ovine Stifle Model as a Preclinical Biomechanical Surrogate for the Human Knee. PhD Dissertation, University of Cincinnati, OH.

Herrmann-Hoesing, L.M., White, S.N., Lewis, G.S., Mousel, M.R., Knowles, D.P., 2007. Development and validation of an ovine progressive pneumonia virus quantitative PCR. Clin. Vacc. Immun. 14 (10), 1274–1278.

Janke, B.H., 1989. Protecting calves from viral diarrhea. Vet. Med. 803–810.

Johnson, R., Kaneene, J.B., 1993a. Bovine leukemia virus. Part II: risk factors of transmission "Infectious Disease in Food Animal Practice." The Compendium Collection. Veterinary Learning Systems, Trenton, NJ.

Johnson, R., Kaneene, J.B., 1993b. Bovine leukemia virus. Part III: zoonotic potential, molecular epidemiology and an animal model "Infectious Disease in Food Animal Practice." The Compendium Collection. Veterinary Learning Systems, Trenton, NJ.

Johnson, R., Kaneene, J.B., 1993c. Bovine leukemia virus. Part IV: economic impact and control measures "Infectious Disease in Food Animal Practice." The Compendium Collection. Veterinary Learning Systems, Trenton, NJ.

Johnson, R., Kaneene, J.B., 1993d. Bovine leukemia virus. Part I: descriptive epidemiology, clinical manifestations, and diagnostic tests Infectious Disease in Food Animal Practice. The Compendium Collection. Veterinary Learning Systems, Trenton, NJ.

Jones, M.L., Meisner, M.D., 2008. Urolithiasis. In: Anderson, D.E., Rings, M. (Eds.), Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders Elsevier, St. Louis, MO, pp. 322–325.

Kimberling, C.V., Ellis, R.P., 1990. Advances in the control of foot rot in sheep. Vet. Clin. North Am. Food Anim. Pract. 6 (3), 671–681.

Kirk, J.H., Glenn, J.S., 1996. Mastitis in ewes. Comp. Cont. Educ. Pract. Vet. 18, 582.

Knowles Jr., D.P., 1997. Laboratory diagnostic tests for retrovirus infections of small ruminants. Vet. Clin. North Am. Food Anim. Pract. 13, 1–11. (Abstract).

Krause, K.M., Oetzel, G., 2006. Understanding and preventing subacute ruminal acidosis in dairy herds: a review. Anim. Feed Sci. Tech. 126 (3), 215–236.

Kuhn, E., 1993. Myotonia congenita (Thomsen) and recessive myotonia (Becker). Nervenarzt 64, 766–769.

Lewin, H.A., 1996. Genetic organization, poymorphism, and function of the bovine major histocampaticulity complex. In: Schook, L.B., Lamont, S.J. (Eds.), The Major Histocompatibility Complex Region of Domestic Animal Species CRC Press, New York, pp. 65–98.

Liu, D., 2009. Handbook of Listeria Monocytogenes. CRC Press, Taylor & Francis Group, Boca Raton, FL.

Lovell, K.L., Matsuura, F., Patterson, J., Baeverfjord, G., Ames, N.K., Jones, M.Z., 1997. Biochemical and morphological expression of early prenatal caprine beta-mannosidosis. Prenatal Diag. 17, 551–557.

Martens, H., Schweigel, M., 2000. Pathophysiology of grass tetany and other hypomagnesemias: implications for clinical management. Vet. Clin. North Am. Food Anim. Pract. 16 (2), 339–368. WB Saunders, Philadelphia, PA.

Maurin, M., Raoult, D., 1999. Q fever. Clin. Microbiol. Rev. 12 (4), 518–553.

McAllister, M.M., Dubey, J.P., Lindsay, D.S., Jolley, W.R., Wills, R.A., McGuire, A.M., 1998. Dogs are the definitive hosts of Neospora caninum. Int. J. Parasitol. 28, 1473–1478.

McCappin, N., Murray, R.D., 2011. Some factors affecting pregnancy rate in ewes following laparoscopic artificial insemination. Vet. Rec. 168 (4), 99.

McKellar, Q.A., Jackson, F., 2004. Veterinary anthelmintics: old and new. Trends Parasitol. Oct 20 (10), 456–461.

Morrow-Tesch, J., 1997. Environmental enrichment for dairy calves and pigs. Animal welfare information center. Newsletter 7, 3–8.

NAHMS Dairy Studies, 2007. United States Department of Agriculture, Animal and Plant Health Inspection Service. <http://www.aphis.usda.gov/animal_health/nahms/dairy/#dairy2007>.

Ott, R.S., 1982. Dairy goat reproduction comp. Cont. Ed. Pract. Vet 4, s164–s172.

Pepin, M., Vitu, C., Russo, P., Mornex, J.F., Peterhans, E., 1998. Maedi-visna virus in sheep: a review. Vet. Res. 29, 341–367. (Abstract).

Piontkowski, M.D., Shivvers, D.W., 1998. Evaluation of a commercially available vaccine against Corynebacterium pseudotuberculosis for use in sheep. J. Am. Vet. Med. Assoc. 212, 1765–1768. (Abstract).

Quintin, A., McKellar, L., Jackson, F., 2004. Veterinary anthelmintics: old and new. Trends Parasit. 20 (10), 456–461.

Robbe-Austerman, S., 2011. Control of paratuberculosis in small ruminants. Vet. Clin. North Am. Food Anim. Pract. 27 (3), 609–620.

Rodolakis, A., Salinas, J., Papp, J., 1998. Recent advances on ovine chlamydophilal abortion. Vet. Res. 29, 275–288. (Abstract).

Rodriguez, S.M., Florins, A., Gillet, N., et al., 2011. Preventive and therapeutic strategies for bovine leukemia virus: lessons for HTLV. Viruses 3 (7), 1210–1248.

Rook, J.S., Kopcha, M., Spaulding, K., et al., 1986. The spider syndrome: a report on one purebred flock. Comp. Cont. Educ. Pract. Vet. 8, S402–S405.

Rychlik, T., Krawczyk, A., 2009. Class I marker polymorphism in polish mountain sheep of coloured and white varieties. Ann. Anim. Sci. 9 (4), 385–393.

Salerno, C.T., Droel, J., Bianco, R.W., 1998. Current state of in vivo preclinical heart valve evaluation. J. Heart Dis. 7, 158–162.

Sargison, N.D., 2012. Pharmaceutical treatments of gastrointestinal nematode infections of sheep – Future of anthelmintic drugs. Vet. Parasitol. 189 (1), 79–84.

Scheerlinck, J.P., Snibson, K.J., Bowles, V.M., Sutton, P., 2008. Biomechanical applications of sheep models: from asthma to vaccines. Trends Biotechnol. 26 (5), 259–266.

Sergeant, E.S.G., Marshall, D.J., Eamens, G.J., Kearns, C., Whittington, R.J., 2003. Evaluation of an agar gel immunodiffusion test kit for detection of antibodies to mycobacterium paratuberculosis in sheep. J. Am. Vet. Med. Assoc. 208, 401–403.

Sordillo, L.M., Streicher, K.L., 2002. Mammary gland immunity and mastitis susceptibility. J. Mamm. Gland Biol. Neoplasia. 7 (2), 135–146.

Stafford, K.J., 2007. Alleviating the pain caused by the castration of cattle. Vet. J. 173, 333–342.

Streeter, R.N., 2009. Bloat or ruminal tympany. In: Anderson, D.E., Rings, M. (Eds.), Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders-Elsevier, St. Louis, MO, pp. 9–11.

Stuen, S., Longbottom, D., 2011. Treatment and control of chlamydophilal and ricketsial infections in sheep and goats. Vet. Clin. North Am. Food Anim. Pract. 27 (1), 213–233.

Titi, H.H., Kridli, R.T., Alnimer, M.A., 2010. Estrus synchronization in sheep and goats using combinations of GnRH, progestagen and prostaglandin F2alpha. Reprod. Domest. Anim. 45 (4), 594–599.

Underwood, W.J., Rook, J.S., 1992. Toxoplasmosis infection in sheep. Compend. Contin. Educ. Pract. Vet. 14, 1543–1548.

United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA/APHIS), Animal Health. <http://www.aphis.usda.gov/wps/portal/aphis/ourfocus/animalhealth>.

United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA/APHIS), 2012. Animal Health – Animal Diseases – Scrapie Disease Information – Eradication Program. <www.aphis.usda.gov/animal_health/animal_diseases/scrapie>.

United States Food and Drug Administration; Animal Medicinal Drug Use Clarification Act of 1994 (AMDUCA). <http://www.fda.gov/AnimalVeterinary/GuidanceComplianceEnforcement/ActsRulesRegulations/ucm085377.htm>.

Uzal, F.A., Songer, J.G., 2008. Diagnosis of clostridium perfringens intestinal infections in sheep and goats. J. Vet. Diagn. Invest. 20 (3), 253–265.

Van Amstel, S.R., 2009. Noninfectious disorders of the foot. In: Anderson, D.E., Rings, M. (Eds.), Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders-Elsevier, St. Louis, MO, pp. 222–234.

Van Metre, D.C., 2009. Hemorrhagic bowel syndrome. In: Anderson, D.E., Rings, M. (Eds.), Current Veterinary Therapy: Food Animal Practice, fifth ed. Saunders-Elsevier, St. Louis, MO, pp. 55–57.

Wall, R.J., Kerr, D.E., Bondoli, K.R., 1997. Transgenic dairy cattle. Genetic engineering on a large scale. J. Dairy Sci. 80, 2213–2224.

Weil, J., Eschenhagen, T., Magnussen, O., et al., 1997. Reduction of myocardial myoglobin in bovine dilated cardiomyopathy. J. Mol. Cell. Cardiol. 29, 743–751.

Welch, R.D., Ashman, R.B., Baker, K.J., Browne, R.H., 1996. Intraosseus infusion of prostaglandin E2 prevents disuse-induced bone loss in the tibia. J. Orthop. Res. 14, 303–310.

Womack, J.E., 1998. The cattle gene map. Comparative gene mapping. Inst. Lab. Anim. Res. J. 39, 153–159.