# Appendix

## Appendix 8.1 Infectious Diseases

Infection is the colonization of a host animal by organisms. If the infection results in pathological consequences, the infection is termed a disease. Pathogens that cause infectious diseases can be species specific, shared with other species, or zoonotic (transmissible between animals and humans). They can be spread directly from animal to animal, or indirectly via the environment or on other animals. Some pathogens survive in other host species or the environment. Some diseases are caused by the interaction of multiple pathogens (Reeves, 2006).

### A8.1.1 Simple pathogen host diseases

These occur when a susceptible animal is exposed to a dose of a specific pathogen that is itself sufficient to cause disease. The disease can be controlled by removing the infected animals (isolation or culling) or by removal of the pathogen (by hygiene practices or by vaccination).

### A8.1.2 Viral diseases

Viruses produce disease by replicating inside cells to cause degeneration and cell death (this can cause inflammation and sickness, as described in Section 8.2). For example, infectious bovine rhinotracheitis virus can cause epithelial necrosis and ulceration. Many viruses are very contagious and can cause high mortality. Viruses can be shed in saliva, mucus, aerosols and/or faeces. As the virus in these secretions is frequently inhaled and/or ingested, the primary replication often occurs in the mucosa of the respiratory and/or intestinal tracts (Patel and Heldens, 2009). Other potential routes are ocular, venereal, transplacental and percutaneous (e.g. by biting vectors). The virus can spread to local lymph nodes, or be spread via infected leucocytes to organs such as the liver, kidneys and lungs (viraemia). The type of cellular damage and the consequences of this damage to physiological function depend on the particular virus and the organs affected; for example, some cause focal haemorrhages (in the liver and kidneys), secretions (in the lungs), oedema and other signs of inflammation that can be readily observed in external mucosa (Patel and Heldens, 2009). Many viruses can damage leucocytes, be immunosuppressive and increase susceptibility to disease. Examples in poultry are infectious bursal disease virus and Marek's disease virus (Dohms and Saif, 1984). Some viruses, such as equine infectious anaemia virus, can be transmitted mechanically by blood-feeding insects and by ingestion of milk/colostrum. Equine infectious anaemia virus replicates in macrophages in the liver and spleen, causing fever, jaundice, haemolytic anaemia, immune complex glomerulonephritis and organ inflammation oedema (Patel *et al.*, 2012). Other viruses are latent in an animal and only cause disease if the animal is challenged by other infections, stressors and other factors that affect immunocompetence. Feline immunodeficiency virus can cause acute disease that is followed by an immune response that can control the viraemia. However, this is followed by a latent stage during which the immune system is slowly destroyed, leading to immunodeficiency, weight loss, anaemia and increased viral replication (Patel *et al.*, 2012). Feline leukaemia virus causes tumours (lymphomas from infected lymphocytes) and several immune response mediated diseases, including immune complex glomerulonephritis, autoimmune haemolytic anaemia, thrombocytopaenia and chronic progressive polyarthritis (Patel *et al.*, 2012).

Viruses are important causes of enteric and respiratory diseases: examples of viral diseases in cattle are bovine viral diarrhoea (BVD) and several viral infections of the respiratory tract, including infectious bovine rhinotracheitis, bovine parainfluenza-3 and bovine syncytial virus. Bovine respiratory syncytial virus can cause severe interstitial pneumonia. The virus damages the bronchial epithelium causing degeneration, necrosis and hyperplasia. The virus activates macrophages to release cytokines. The bronchioles can fill with mucopurulent exudate. Haemorrhage, oedema and emphysema can occur. These changes can cause coughing, nasal discharges, increased respiration rate, fever and anorexia. If the disease progresses, the bronchi can be obstructed, leading to dyspnoea, depression and coma (Larsen, 2000).

If exotic viruses, that is those that are not normally present in a population, are introduced, they have great potential to spread rapidly in a vulnerable population that does not have adequate immunity to that virus. Vaccination is important in reducing the risk of the spread of endemic and non-endemic viral diseases. Many viral diseases in dogs and cats are controlled by routine vaccination. However, they can be seen in situations such as animal shelters, where many animals without adequate immunity are housed together in a stressful environment. Feline herpesvirus and feline calicivirus are common causes of upper respiratory tract infection. Canine and feline parvoviruses can replicate in lymphoid tissues, myocardial cells and small intestinal mucosa to cause haemorrhagic enteritis and myocarditis. Canine distemper virus can affect multiple organs, causing rhinitis, tracheobronchitis, interstitial pneumonia, hyperkeratosis of the nose and foot pads, catarrhal enteritis, necrotizing encephalitis and conjunctivitis (Pesavento and Murphy, 2014).

## A8.1.3 Bacterial diseases

Bacterial diseases are common in livestock and can cause a range of clinical conditions with welfare significance, including digestive diseases, respiratory diseases, mastitis, skin diseases, lameness (feet, joint and skeletal problems), abscesses (Fig. 8.8E), septicaemia, sepsis, toxaemia and endotoxaemia (Page and Gautier, 2012). Bacteria are responsible for many common poultry diseases of the respiratory system, reproductive tract and skin (Agunos *et al.*, 2013). Bacterial infections can be secondary to or combine with viruses to cause disease.

**Fig. 8.8E. Sheep with tooth abscess. (Courtesy of Dr Paula Menzies.)**

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Pathogenic bacteria cause disease by producing necrosis and pus (mastitis in cattle, strangles in horses, arthritis in pigs and caseous lymphadenitis in sheep, Figs 8.9E and 8.10E); secreting toxins (*Escherichia coli* can cause acute enterotoxic colibacillosis in pigs, calves and lambs with watery diarrhoea, dehydration and acidosis); or replicating within macrophages and host cells (salmonellosis) (Cheville, 2006). These pathophysiological changes can cause inflammation and sickness, as described in Section 8.2. For example, *Actinobacillus pleuropneumoniae* can cause severe pneumonia in pigs (Baarsch *et al.*, 2000). Acute-phase proteins and cytokines develop in the serum and lungs, respectively. The alveoli contain fibrinous exudate, blood and necrotic cellular debris, and fluid and fibrin accumulate in the pleural cavity. The pigs can show increased respiratory rate and dyspnoea, vomiting, depression and inappetence. The lungs become consolidated, oedematous and haemorrhagic.

**Fig. 8.9E. Sheep with caseous lymphadenitis abscess caused by infection with the bacterium *Corynebacterium pseudotuberculosis*. (Courtesy of Dr Paula Menzies.)**

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**Fig. 8.10E. Lungs of sheep with caseous lymphadenitis abscess caused by infection with the bacterium *Corynebacterium pseudotuberculosis*. (Courtesy of Dr Paula Menzies.)**

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The outer layer of gram-negative bacteria contains lipopolysaccharide or endotoxin that is responsible for many of the signs of sickness seen in this type of bacterial disease. Meloxicam (an NSAID) can reduce some of the responses (increased respiration rate and vomiting) of pigs to *E. coli* endotoxin (Friton *et al.*, 2006). Although there is no endotoxin in gram-positive bacteria, they do contain other biologically active chemicals. Both gram-positive and gram-negative bacteria can excrete exotoxins that are potent antigens. In neonatal animals, endotoxaemia is commonly associated with failure of passive transfer of colostral antibodies and the subsequent development of septicaemia (Moore and Barton, 2003). Gram-negative bacteria such as *E. coli*, *Mannheimia haemolytica* and *Pasteurella multocida* are common components of neonatal diarrhoea and respiratory disease in calves (Fig. 8.11E). Calves with *E. coli*-induced diarrhoea can develop dehydration due to water and electrolyte losses (Bywater and Logan, 1974). Bacteraemia from *E. coli* can develop into endotoxaemia and septicaemia (Ballou *et al.*, 2011). Plasma concentrations of cytokines and acute-phase proteins can increase, and the calves can develop acute hypoglycaemia and leucopenia. The calves can become depressed, lethargic and febrile. Administration of lipopolysaccharide produces similar effects, i.e. increases in cytokine and acute-phase protein concentrations, and sickness, i.e. increases in body temperature, respiration rate and heart rate, and reduced feed intake. This can be followed by respiratory distress, coughing and lateral lying (Plessers *et al.*, 2015).

**Fig. 8.11E. Post-mortem signs of pneumonia in a calf.**

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Mastitis is a common bacterial disease affecting dairy cows, sheep (Fig. 8.12E) and pigs. The inflammatory reaction is a source of pain and discomfort, and some types of mastitis, for example coliform mastitis, can cause sickness (Leslie and Petersson-Wolfe, 2012). Signs of pain and sickness can be reduced by NSAIDs (Vangroenweghe *et al.*, 2005; Fitzpatrick *et al.*, 2013). Some of the signs of pain and sickness seen in cows with *E. coli* mastitis are summarized in Table 8.2.

**Fig. 8.12E. Sheep with mastitis. (Courtesy of Dr Paula Menzies.)**

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Stress can alter the growth and/or virulence of bacterial pathogens (Verbrugghe *et al.*, 2012) and the effects of the bacteria on the animal. In piglets, weaning associated with increases in adrenocorticotropic hormone (ACTH) and cortisol can increase the frequency of clinical signs (vomiting, diarrhoea and somnolence) shown in response to the administration of bacterial endotoxin (Kanitz *et al.*, 2002). Repeated social isolation can also affect the severity of some of the clinical responses of piglets to bacterial endotoxin (Tuchscherer *et al.*, 2006). Although there are numerous welfare benefits in providing environmental enrichment (Newberry, 1995), it is interesting to note that some types of environmental enrichment provided to some animals can increase the risk of disease after bacterial challenge (Huff *et al.*, 2003).

Antibiotics (the term is used in the broadest sense to include naturally occurring, semi-synthetic and synthetic compounds with antimicrobial activity) are important for the treatment of clinical bacterial infections (therapy), for preventing clinical infections (prophylaxis) (Refsdal, 2000; McEwen, 2006) or for metaphylaxis, i.e. the treatment of a group of animals after the occurrence or diagnosis of clinical disease in part of the group, with the aim of treating the clinically sick animals and controlling the spread of disease to animals in close contact and at risk, or those that may already be subclinically infected (Page and Gautier, 2012; Gleeson and Collins, 2015). However, there are restrictions on antibiotic use in animals because antibiotic resistance is causing major problems in human medicine (Marshall and Levy, 2011). In addition, in many intensive systems, there can be a tendency to use antibiotics to mask disease rather than to correct underlying defects. Routine use of antibiotics in the feed of pigs and broilers to promote growth by controlling subclinical disease has been either banned or discouraged. To rear animals without the use of antibiotics to control bacterial infections and avoid the suffering that can occur due to bacterial diseases requires optimal husbandry, health and disease control measures (Gleeson and Collins, 2015) (see Appendix 8.2 on disease control). Gaucher *et al.* (2015) reported that it was possible to rear broilers without the use of antibiotic and anticoccidial drugs in the feed or water and to replace them with an anticoccidial vaccine, feed and water supplements and optimized rearing conditions. Although growth was lower, and enteritis occurred, mortality was not significantly different compared with units that used antibiotics.

## A8.1.4 Parasitic diseases

Parasites can cause varying degrees of inflammation, discomfort and anorexia (Kyriazakis *et al.*, 1998). They can stimulate an immune response (McRae *et al.*, 2015), and this can sometimes cause disease that is associated

**Table 8.2.** Signs of pain and sickness in bovine *Escherichia coli* mastitis.

| Pain | Reference | Sickness | Reference |
|---|---|---|---|
| Signs of inflammation: heat, swelling, pain | Lohuis *et al.* (1991)<br>Vangroenweghe *et al.* (2005)<br>Banting *et al.* (2008)<br>Hovinen *et al.* (2008)<br>Rasmussen *et al.* (2011)<br>Fitzpatrick *et al.* (2013) | Fever | Lohuis *et al.* (1991)<br>Banting *et al.* (2008)<br>Rasmussen *et al.* (2011)<br>Zimov *et al.* (2011)<br>Fogsgaard *et al.* (2012)<br>Fitzpatrick *et al.* (2013) |
| Hyperalgesia in infected quarter | Fitzpatrick *et al.* (2013) | ↓ Feed intake | Rasmussen *et al.* (2011)<br>Zimov *et al.* (2011)<br>Fogsgaard *et al.* (2012)<br>Sepúlveda-Varas *et al.* (2016) |
| ↓ Hind-leg weight shifting | Chapinal *et al.* (2013) | ↓ Grooming | Fogsgaard *et al.* (2012) |
| | | ↓ Rumination | Vangroenweghe *et al.* (2005)<br>Banting *et al.* (2008)<br>Zimov *et al.* (2011)<br>Chapinal *et al.* (2013) |
| ↓ Lying duration | Cyples *et al.* (2012)<br>Medrano-Galarza *et al.* (2012)<br>Yeiser *et al.* (2012) | ↑ Lying duration | Fogsgaard *et al.* (2012) |
| ↑ Respiration rate | Banting *et al.* (2008)<br>Vangroenweghe *et al.* (2005) | ↓ Competition at feeder | Sepúlveda-Varas *et al.* (2016) |
| ↑ Heart rate | Lohuis *et al.* (1991)<br>Vangroenweghe *et al.* (2005) | | |
| ↑ Serum cortisol concentration | Zimov *et al.* (2011) | | |

with sickness (Colditz, 2003; Williams, 2011). In fish, parasites can attach to or cause lesions to the sensory apparatus (eyes, nares, inner ear and lateral line) that have the potential to affect feeding and anti-predator behaviour (Barber, 2007).

Some protozoa can kill host cells; for example, coccidia and cryptosporidia damage intestinal epithelial cells in poultry and young ruminants (Fig. 8.13E) and cause diarrhoea. Babesia, transmitted by ticks, can destroy erythrocytes to cause anaemia in cattle. In pigs, sarcocystis can cause sickness (raised body temperature, increased lying and reduced feeding, drinking and rooting) and muscle damage as it reproduces and migrates through the body (Reiner *et al.*, 2009).

Adult parasitic worms can cause disease by mechanical obstruction of ducts (ascarides in pig intestines); by sucking blood and causing anaemia (*Haemonchus contortus* in sheep, Fig. 8.14E); and by causing diarrhoea (parasitic gastroenteritis in sheep). Enteric parasites can cause raised plasma cortisol concentration (Prichard *et al.*, 1974; Fleming, 1997) and debilitate animals by causing inappetence, protein loss (from leakage of plasma protein and damage to the lining of the gastrointestinal tract) and weight loss (Holmes, 1987). Larvae

**Fig. 8.13E. Diarrhoea in young lambs, due to coccidiosis. (Courtesy of Dr Paula Menzies.)**

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**Fig. 8.14E. Anaemia in sheep due to *Haemonchus contortus*. (Courtesy of Dr Paula Menzies.)**

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can pass through the body and cause damage (granulomatous lesions) to various organs.

Ticks can transmit a variety of different types of pathogens. They also cause direct damage due to toxic effects, irritation, allergy and a general loss of condition. Culicoides (biting midges) can cause serious irritation and transmit pathogenic viruses such as bluetongue. Lice can cause skin irritation. In sheep, the mites (*Psoroptes ovis*) that cause sheep scab can cause scratching, inappetence, emaciation and dehydration, and sometimes mortality from secondary infections (Corke and Broom, 1999; Milne *et al.*, 2008). Sheep can also experience skin irritation from sarcoptic mange (Fig. 8.15E). In pigs, mites cause rubbing due to skin irritation (Goyena *et al.*, 2015). In laying hens, red mites can cause irritation, anaemia, reduced growth and occasionally death (Kilpinen *et al.*, 2005). Sea lice erode the skin of farmed fish, causing tissue damage, and may also act as a vector of other diseases (Ashley, 2007).

**Fig. 8.15E. Sheep with sarcoptic mange caused by mites (*Sarcoptes scabiei* var. *ovis*). (Courtesy of Dr Paula Menzies.)**

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Sheep fly strike (Wall and Lovatt, 2015) is a painful condition associated with inflammation, irritation and sometimes death. Blowflies lay their eggs on the sheep, and the maggots burrow into the flesh and poison the sheep with the ammonia that they secrete. Sheep experience fever and reduced feed intake, and have raised plasma concentrations of cortisol, cytokines and acute-phase proteins (Colditz *et al.*, 2005). Surgical procedures, such as tail docking and mulesing, that have been used to reduce the risk of fly strike can themselves cause pain (Plant, 2006). The larvae from the sheep nose bot fly, *Oestrus ovis*, can damage the nasal mucosa (Fig. 8.16E).

**Fig. 8.16E. Sheep with nose bot fly, *Oestrus ovis*. (Courtesy of Dr Paula Menzies.)**

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The treatment and control of parasites are based on the life cycle of the particular parasite. Adult worms lay eggs that pass out of the host animal in the faeces. Some parasites have an intermediate host (snails for liver fluke and earthworms for lungworms in pigs). Because an animal can ingest the parasite while it grazes, control is based on separation of the animal from its faeces or reducing pasture contamination by avoiding overstocking and by grazing rotation. Medicinal products can reduce the numbers of eggs passed in the faeces or kill external parasites. However, parasite resistance to drug use is an increasing problem (Sangster, 2001). Vaccines can stimulate immunity to some parasites (Hein and Harrison, 2005), e.g. lungworm in cattle and coccidia in poultry. Table 8.3 shows the diagnosis of different causes of death in different housing systems for laying hens, and Fig. 8.17E shows cumulative mortality in the different systems.

**Fig. 8.17E. Mortality in laying hen housing systems. Box plots for mortality of laying hens between 60 and 80 weeks of age in each housing system using data from ten studies (3851 flocks). (From Weeks et al., 2016, using a Creative Commons Public License; http://creativecommons.org/licenses/by/4.0/.)**

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# Appendix 8.2 Disease Control

## A8.2.1 Risk factors for disease

The philosophy that forms the basis for animal health/preventive medicine is that disease ‘prevention is better than cure’ (European Commission, 2007). The maintenance of health status is a constant challenge. Animals are always at risk of infection, and as some existing infectious diseases are controlled, new ones emerge. Endemic infectious diseases remain in an animal population because the existing disease control measures are not effective. Understanding the underlying causes and the mechanisms by which infectious disease spreads is vital to controlling disease. Contagious diseases can be transmitted by direct physical contact with other

**Table 8.3** Causes of mortality in 914 laying hens from different housing systems submitted for post-mortem examination to the National Veterinary Institute in Uppsala, Sweden, between 2001 and 2004. (From Fossum *et al.*, 2009.)

| | | | Per cent of flocks in each housing system that were diagnosed with: | | | |
|---|---|---|---|---|---|---|
| Housing system | Per cent of hens in Sweden housed in each system | No. of examined flocks with increased mortality | Bacterial diseases | Viral diseases | Parasitic diseases | Cannibalism |
| Cages | 56 | 20 | 65 | 30 | 10 | 5 |
| Litter-based | 39 | 129 | 73 | 12 | 18 | 19 |
| Free range | 5 | 23 | 74 | 4 | 22 | 26 |

*Note:* Cages include conventional and enriched. Litter-based includes single-tiered floor and multi-tiered aviary systems. Free range includes hens housed indoors on litter with access to outdoor pens, and includes organic systems.

animals, while infectious diseases can be transmitted not only by infected animals but also via air, water, food and many other vectors, including wild mammals and birds, invertebrates, vehicles, humans and environmental contamination.

Thrusfield (2007, p. 22) defines epidemiology as 'the study of disease in populations and of the factors that affect its occurrence'. Epidemiological methods can be used to identify risk factors for disease, and these techniques are especially useful when dealing with diseases that are multifactorial in nature. Complex, pathogen–animal–environment diseases can be produced by simultaneous infection with one or more pathogens and by interaction between the infectious agents and predisposing, enabling or reinforcing factors. Such factors include the genetics or age of the animal, and their nutrition, environment and management system. An example is bovine respiratory disease (Webster, 1983; Taylor *et al.*, 2010). These complex and multifactorial diseases can occur when the potential pathogen is present in the environment, on or in the animal, but does not cause disease until the equilibrium between pathogen, animal and environment is disturbed (Webster, 1992; Thrusfield, 2007). Control of these types of diseases requires a whole herd/flock approach and consideration of the husbandry, management, nutrition and environment. Examples of poor husbandry that can predispose to disease include overcrowding, mixing of different ages, obtaining animals from several sources, poor air hygiene, poor drainage and bedding, unhygienic food and watering equipment, inappropriate nutrition and inadequate cleaning and disinfection (Sainsbury, 1998). An example of a risk factor for disease was the lower pre-partum feed intake in dairy cows that subsequently developed post-partum metritis compared with the feed intake of cows that remained healthy during the post-partum period (Huzzey *et al.*, 2007). However, an association does not demonstrate causation, and the underlying pathophysiology that links a risk factor to a disease can sometimes be difficult to identify. The post-partum bacterial proliferation in the uterus that results in metritis tends to occur after the endometrium has been damaged by factors such as obstetrical complications and retained fetal membranes (Gilbert, 2016). It is possible that a pre-partum energy deficit as a consequence of the reduced feed intake reduces immunocompetence (Hammon *et al.*, 2006; Galvão *et al.*, 2010) and thereby facilitates bacterial growth or increases the risk of retained fetal membranes (Gilbert, 2016). Whether cows that subsequently develop metritis have a tendency to be less dominant at the feeding bunk – i.e. they are subordinate compared to cows that remain healthy (Huzzey *et al.*, 2007) – resulting in increased pre-partum stress and reduced immunocompetence, is not clear. The basis of health management and disease prevention is the adoption of an integrated approach to the management of a group of animals to rectify underlying problems with the system of production or management on a unit rather than focusing on just the diagnosis and treatment of individual animals (LeBlanc *et al.*, 2006).

## A8.2.2 Disease control measures

In most countries, the primary responsibility for the health of animals rests with the owner of the animals. There are many factors influencing the voluntary adoption of disease control measures by individual farmers. In developed countries, some of the main factors include: the perceived risk of specific diseases and the cost of the disease to the individual farmer; the cost-effectiveness and perceived efficacy and practicability of the control measures; the ability of advisors to transfer the knowledge and understanding of relevant information within the context of the overall operations of the unit, and especially in a participatory manner that facilitates engagement and ownership by the farmer/producer of the design and operation of programmes; the perceived ability to affect change; the effects on the welfare of the animals; and the sense of pride that the producer has in the management of his or her unit (Valeeva *et al.*, 2007; Kristensen and Jakobsen 2011a; Dehove *et al.*, 2012; Main and Mullan, 2012; Whay *et al.*, 2012; Garforth *et al.*, 2013; Alarcon *et al.*, 2014).

In many, but not all, parts of the world, governments take responsibility for securing external borders to prevent outbreaks of exotic diseases, for disease surveillance and, where necessary, control programmes. Collective action from industry can assist by developing coordinated action plans (European Commission, 2007; Bennett, 2012). For example, the Norwegian dairy goat industry's voluntary disease eradication programme to control caprine arthritis encephalitis, caseous lymphadenitis and Johne's disease appears to have produced some measurable improvements in animal welfare (Muri *et al.*, 2016).

In some developing countries, the effectiveness of disease control measures can be limited by economic and other resources, infrastructure problems, knowledge of which diseases are present and their impact, the movement of animals, the presence of disease in wild animals and the lack of effective veterinary services (Perry and Grace, 2009; Weaver *et al.*, 2012; Smith *et al.*, 2014). Other than for the eradication of rinderpest (Anderson *et al.*, 2011), the prevalence of many epidemic and endemic livestock diseases remains problematic in the developing world (Perry *et al.*, 2013).

Legislation and market requirements to conform to farm assurance schemes and product standards can provide motivation to adopt disease control measures (Main and Mullan, 2012). In the EU, welfare codes and legislation require that management risk factors that have the potential to cause health problems in livestock are controlled.

The main approaches used to control infectious diseases in a unit attempt to increase resistance to infection, remove sources of infection and prevent new contacts that result in the transmission of infection. Factors that affect the ability of animals to resist disease include: the genotype and phenotype of the animal; antibody status, affected by passive transfer of maternal antibodies (e.g. colostrum management in neonatal calves, Lorenz *et al.*, 2011) and vaccination programmes; and factors influencing immunosuppression (Dietert *et al.*, 1994), such as social rank (Hessing *et al.*, 1994), stressors (Shini *et al.*, 2010), thermal extremes (Wathes *et al.*, 1989), inadequate nutrition or changes in nutrition (Pluske *et al.*, 2002) and mixed infections (Hoerr, 2010). Breeding to improve resistance to disease is an active area of research (Berry *et al.*, 2011; Bishop and Woolliams, 2014), and is seen as one mechanism to reduce the welfare consequences of disease (Reiner, 2009).

Factors that affect the level of exposure to pathogens include inadequate cleaning and disinfection (Mannion *et al.*, 2007) (Figs 8.18E and 8.19E), high stocking density, housing design and ventilation resulting in poor air quality (Robertson *et al.*, 1990; Hamilton *et al.*, 1999; Stärk, 2000), and exposure to other groups of animals (Maunsell and Donovan, 2008). In the pig and poultry industries, large breeding companies can restrict the sources of breeding stock and the risk of disease transmission. High pig herd health status can be established by interrupting opportunities for disease transmission from the sow to her piglets by obtaining caesarean-derived, colostrum-deprived piglets, removing piglets immediately after farrowing and obtaining piglets from known high health status herds (Reeves, 2006).

**Fig. 8.18E. Thorough cleaning and disinfection of calf pens.**

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**Fig. 8.19E. Rinsing of calf pens after disinfection.**

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## A8.2.3 Biosecurity

Biosecurity on animal units is required to reduce the risk of infectious disease occurring or spreading to other animals. Best practice involves relatively prescriptive guidelines designed to prevent disease-causing agents from entering, spreading within or leaving a property and spreading to other units (Ssematimba *et al.*, 2013). However, many individual producers are reluctant to adopt strict biosecurity procedures (Heffernan *et al.*, 2008; Kristensen and Jakobsen, 2011b). This may be due in part to the costs involved in implementing the measures (Siekkinen *et al.*, 2012), but many other factors influence biosecurity practices on farms (Toma *et al.*, 2013). Interestingly, concern by British cattle and sheep farmers for animal welfare has not been reflected by the adoption of optimal biosecurity practices (Toma *et al.*, 2013). Animals newly brought on to the unit present the greatest risk of infectious disease spread (Mee *et al.*, 2012). Information on their health status should be obtained and the animals isolated for a suitable period. Only essential visitors should be allowed on to certain units such as pig, poultry or laboratory animal sites. They should follow disinfection procedures, wear unit clothing and footwear, avoid visits to other units for an agreed period before and afterwards, and record their visit. Loading facilities and feed bins should be sited at the unit perimeter. Vehicles that visit other units should be kept off the unit wherever possible. Domestic pets and wild animals (birds and rodents) should be discouraged. Free-range poultry flocks might be required to be housed during an outbreak of avian influenza to prevent disease transmission via wild birds (Lister and van Nijhuis, 2012). Animal units should be sited as far as is practicable from other units, as this will reduce the risk of spread of airborne infectious diseases (Stärk, 1999). The animals should be kept in age-segregated groups in all-in/all-out systems, with a cleansing and disinfection programme that is documented, implemented and checked for effectiveness (Reeves, 2006). Cleaning and disinfection of animal housing are facilitated by flat, featureless walls and floors, and an absence of internal structure. Enhancements to animal housing to facilitate behaviour can be constrained by concerns about disease transmission associated with social housing, increased contact with excreta, and difficulty cleaning and disinfecting enclosures containing soil and natural and porous materials. Although care should be taken, especially when housing young animals, some disease concerns have not proved to be major obstacles to the adoption of alternative housing (Newberry, 1995).

### A8.2.4 Culling to control infectious disease

In many countries, considerable resources have been allocated to control or eradicate important infectious diseases. However, globalization and increased international trade of animals and animal products have increased the risk of disease spread (Thiermann, 2004). Examples are provided by Zepeda *et al.* (2001), Fèvre *et al.* (2006) and de La Rocque *et al.* (2011) of the relationships between animal movement and the spread of infectious disease. The World Organisation for Animal Health (OIE) website (www.oie.int) provides information on current disease distribution throughout the world. The means of dealing with an exotic disease outbreak such as foot-and-mouth disease or avian influenza include early detection of disease, rapid killing of all known infected animals, tracing of all high-risk contacts, application of herd quarantine and movement restrictions, testing of populations at risk and, in some instances, the application of pre-emptive slaughter or strategic vaccination (Whiting, 2003). Although there are different ethical positions (Wright *et al.*, 2010), culling large numbers of animals can be justified on welfare grounds: to eliminate suffering in diseased animals, to prevent suffering in susceptible animals due to the spread of disease; and to prevent welfare problems due to overcrowding or other deteriorating animal husbandry conditions because of movement restrictions (Whiting, 2003; Raj, 2008; East *et al.*, 2014). The killing of large numbers of animals in a short period is difficult to achieve humanely, due to the limited availability of skilled slaughtermen, handling problems, time constraints and, in some cases, the lack of a suitable humane method of killing (Crispin *et al.*, 2002; Whiting, 2003). The animal welfare procedures to be adopted during mass culling are described by Berg (2012), Gavinelli *et al.* (2014) and OIE (2016).

### A8.2.5 Health plans

A written health and welfare plan is a management tool, matched to the individual needs of each livestock unit, that is drawn up in consultation with the unit's veterinarian, to ensure that preventive and treatment regimes are planned, the health performance is recorded and reviewed and appropriate action plans developed (Main *et al.*, 2003). Health plans form part of many quality assurance schemes, and their presence can be used in welfare assessments as evidence of best practice. Such plans set out health and husbandry activities that cover the whole year's cycle of production, and include strategies to prevent, treat or limit existing disease problems (both infectious and non-infectious). It is normal practice for stockpeople to undertake routine treatments and disease control measures under the direction of the herd veterinarian (Alban and Agger, 1996). It is therefore important that the plan should provide for regular veterinary visits to advise on animal health and include: standard operating procedures for biosecurity arrangements; procedures for purchased stock; vaccination policy and timing in relation to perceived disease risk (Scott *et al.*, 2007; Richens *et al.*, 2016); isolation procedures; external and internal parasite control; the timing and dose of any necessary medical treatments; and any specific disease programmes. Important variables are recorded, including the number of animals, age, breed and performance values such as production, water consumption, number of animals found dead, number of culls, treatment and medicine records. A veterinary intervention point is set to decide when normal values have reached an unacceptable level. When the veterinarian visits, clinical notes, post-mortem examinations or laboratory work that has been carried out are added to the health plan. Useful health information can also be recorded using feedback from pathology found at the slaughterhouse during meat inspection (Green *et al*., 1997; Phythian *et al*., 2014).

In companion animal practice, regular preventive-medicine consultations, for example during visits for vaccination, provide opportunities for a routine health check, discussion and identification of health issues, and control of parasites and reproduction (Robinson *et al*., 2016).

### A8.2.6 Influence of production system

Each system of husbandry has its characteristic disease problems, but the health of the animals within each system is also dependent on the stockmanship and disease prevention and control measures that are in place. Intensification in the dairy, pig and poultry sectors has provided more opportunities for improved management and control of several endemic diseases (Perry *et al*., 2013). Intensive systems where the animals are housed can provide greater biosecurity than systems where the animals are kept outside. However, when large numbers of animals are housed on one site, the risk of bacterial and viral diseases (such as enzoonotic pneumonia and enteric disorders in pigs and calves) is high. In general parasitic diseases are more common in extensive systems. For example, in laying hens there is an increased risk of mortality from bacterial diseases, parasites and cannibalism in litter-based and free-range systems compared to cages, but a reduction in viral conditions (Fossum *et al.,* 2009) (Table 8.3). However, in Switzerland, the change from conventional battery cage housing systems to alternative systems was not followed by increased mortality due to coccidia and other parasites. There was a reduction in mortality due to viral diseases, but mortality due to bacterial infection increased. Vaccination against viral diseases and coccidiosis, together with de-worming strategies, paddock rotation, biosecurity and other disease control measures accompanied the changes in housing system (Kaufmann-Bart and Hoop, 2009). Another potential health issue associated with the choice of housing system for laying hens are the greater dust and ammonia concentrations in litter compared with caged systems (David *et al*., 2015a, b). Weeks *et al*. (2016) found greater mortality in flocks kept in non-cage systems than in caged systems (Figure 8.17E). For reviews of the health and welfare aspects of different housing systems for laying hens, see Lay *et al*. (2011) and Lister and van Nijhuis (2012).

Reliable evidence to evaluate the increased risks to animal health and welfare in organic systems of production due to failure to provide standard preventive medicines for disease control is difficult to identify. Comparisons between organic and conventional systems are complicated by confounding factors in each system that affect the risk of disease, e.g. differences in genotype, pasture management. Depending on the type of disease, some diseases have a greater prevalence in organic systems whereas other diseases have a lower prevalence (Kijlstra and Eijck, 2006; Marley *et al*., 2010; Edwards *et al*., 2014; Gocsik *et al*., 2014).

## Appendix 8.3 Non-infectious Diseases

### A8.3.1 Production-related diseases

Some diseases are considered to have particular welfare significance because they are likely to have occurred as a direct consequence of the management system used (Rollin, 2009), but are tolerated because they do not reduce the economic profitability associated with the management system. Genetic selection has increased production, but in some cases, this has been accompanied by an increased risk of health problems (Rauw *et al*., 1998). Many metabolic diseases are associated with increased metabolism, rapid growth rate, or high production that results in the failure of a body system because of the increased workload on that organ or system (Julian, 2005).

In general, the selection of dairy cows for increased milk yield leads to a higher risk of mastitis, metabolic diseases and lameness (Oltenacu and Broom, 2010). Metabolic diseases in dairy cattle, such as hypocalcaemia, hypomagnesaemia and ketosis, are associated with imbalances in the input and output of metabolites required for milk production. During early lactation, dairy cows are in negative energy balance and are susceptible to metabolic and infectious diseases (LeBlanc, 2010).

Cattle offered diets containing insufficient fibre can have an increased risk of developing ruminal acidosis and laminitis (Lean *et al.*, 2008). Milk-fed veal calves have traditionally been reared on milk replacer with a low iron concentration to produce pale-coloured veal with a low myoglobin concentration. A reduction in the availability of iron to form haemoglobin decreases the oxygen-carrying capacity of red blood cells. Unless these veal calves receive additional sources of iron in their diet, the blood haemoglobin concentration is monitored well and, if required, iron supplementation is provided, there is a risk of iron deficiency anaemia. Severe signs can include inappetence, reduced immunity and decreased exercise tolerance (Reece, 1984; Reece and Hotchkiss, 1987; Gygax *et al.*, 1993).

In broilers, difficulty in providing sufficient oxygen to enlarged muscles can cause hypertrophy of the right ventricle of the heart and ascites (Julian, 2000). In layers, osteoporosis is a progressive decrease in mineralized structural bone that leads to bone fragility and susceptibility to spontaneous bone fractures and fractures (Gregory and Wilkins, 1989; Whitehead, 2004). When it occurs later in the laying cycle, it has been called cage-layer fatigue and can cause acute and chronic pain and debility from bone fractures sufficient to cause mortality (Riddell *et al.*, 1968; Webster, 2004). Painful fractures of the sternum/keel bone can occur especially in aviaries, when hens collide with perches (Wilkins *et al.*, 2011; Nasr *et al.*, 2012), while the wing and leg bones can break if handling is rough during depopulation (Gregory and Wilkins, 1989). Genetic selection for laying hens that remain in reproductive condition over a prolonged period increases susceptibility to osteoporosis. During this time, medullary bone, which acts as a labile source of calcium for eggshells, is produced in preference to structural bone. However, as both medullary and structural bone are resorbed over time, there is a progressive loss of structural bone throughout the skeleton (Whitehead, 2004). The strength of bone is dependent on its load-bearing activity and birds kept in housing systems that encourage physical activity have stronger bones.

It has been suggested that several factors associated with increased performance in pigs can predispose to health disorders (Prunier *et al.*, 2010). Examples include consequences of early weaning on enteric disorders, stress of management practices resulting in reduced immunity, effects of rapid growth on leg disorders, metabolic demands on sows due to lactation and frequency of pregnancy, and increased litter size affecting birth weight and availability of colostrum.

### A8.3.2 Genetic diseases

Many diseases have a genetic component. This can be seen clearly in some purebred dogs. Breed standards for some pedigree dogs may have encouraged breeders to select for characteristics that result in health problems (Asher *et al.*, 2009). Certain features of some breeds (such as coat, weight, skin, eyes and shortness of muzzle) have been exaggerated to the detriment of health, and in some breeds there is an increased prevalence of inherited disorders (Stafford, 2006; Collins *et al.*, 2010; Rooney and Sargan 2010). For example, disorders such as entropion and hip dysplasia (Woolliams *et al.*, 2011) are painful, and they may require surgery or prolonged treatment. In brachiocephalic breeds, their head shape can cause problems during whelping, breathing (Hoareau *et al.*, 2012), exercising (especially in heat) and sleeping (Roedler *et al.*, 2013), and their bulging eyes (exophthalmoses) are susceptible to injury.

### A8.3.3 Neoplastic diseases

Neoplasia is not uncommon in companion animals, especially as they grow old (Sleeckx *et al.*, 2011; Schiffman and Breen, 2015). As tumours grow, they can exert pressure on surrounding tissues and cause pain, e.g. bone marrow tumours (Smith *et al.*, 1972; Cheville, 2006). Tumours on the skin or mucous membranes can ulcerate. Pain can also be caused by direct tumour involvement of pain-sensitive structures such as soft tissue, bone, nerves and viscera, or via bone metastases (Lester and Gaynor, 2000; Gaynor, 2008; Fox, 2012). Malignant tumours grow at the site of origin, and also spread via the circulation and lymphatic system to other sites such as the lungs, liver, spleen and kidneys (Seixas *et al.*, 2011). They can cause ill health (emaciation, anaemia and fatigue) and death.

### A8.3.4 Painful conditions arising from physical changes associated with disease

Pain due to mechanical distension can occur in several clinical situations (Hansen, 2000; Mathews, 2000). When the lumen of the gastrointestinal tract is distended due to the accumulation of gas in the stomach or intestine (e.g. bloat due to fermentation, Cheng *et al*., 1998), gastric (Wingfield *et al*., 1974) or intestinal torsion, or intestinal obstruction (as occurs in equine colic, Thoefner *et al*., 2003; Ashley *et al*., 2005), considerable pain can be caused. Horses with severe colic (potentially fatal) can have raised plasma concentrations of cortisol, ACTH, adrenaline (epinephrine) and β-endorphin (Hinchcliff *et al*., 2005; Niinistö *et al*., 2010). When ureteral (kidney stones), urethral (urinary calculi from dietary problems) or biliary (gallstones) ducts are obstructed, fluids accumulate, causing distension and sometimes toxic effects (Catanzaro *et al*., 2015). Mesenteric, gastric, splenic and testicular torsions (twists) and herniation of intestines into the umbilicus and inguinal canal can cause pain. If blood vessels are blocked (thrombosis), blood can accumulate within the vessel, causing pain due to distention, and fluid can leak into the surrounding tissues, causing swelling and further pain. In situations where the blood supply to an organ is restricted by a pathological process or mechanical obstruction, the tissues are deprived of oxygen (ischaemia) and can become necrotic (Snyder, 1989; Catanzaro *et al*., 2015). Neuropathic pain (caused or initiated by a primary lesion or dysfunction in the nervous system) can occur. Examples include soft tissue and bony changes that affect the spinal cord (lumbosacral lesions and intervertebral disc herniation), neoplasia and aggressive conditions such as pancreatitis that can damage intrapancreatic nerves (Mathews, 2008).

### A8.3.5 Parturition and neonatal care

Dystocia (difficult birth) caused by fetal oversize or malposition and obstetrical problems such as vaginal or uterine prolapse can be associated with considerable pain, discomfort and health risks (McGuirk *et al*., 2007; Mainau and Manteca, 2011; Rees, 2016). Veterinary procedures, the use of analgesia and antibiotics, and hygienic practices can reduce the adverse welfare implications associated with obstetrical problems (Scott, 2005). However, they cannot eliminate all of the associated suffering, and if the incidence of dystocia is high, breeding policy should be reviewed. For example, in the double-muscled Belgian Blue breed, calves often have to be delivered by caesarean section, and there is now a case for selecting for smaller calves (Kolkman *et al*., 2010a,b). Dystocia also causes problems in newborn animals from direct physical trauma, delayed passive antibody transfer and subsequent bacterial infections (Murray and Leslie, 2013). Newborn animals are susceptible to mortality from hypothermia, infections, injuries and predation, and require additional care (Mellor and Stafford, 2004).

### A8.3.6 Nutrition

Dietary deficiencies, imbalances and contaminants can also cause clinical disease (Fig. 8.20E). Metabolic diseases can occur when animals consume toxic contaminants in their diet, e.g. from fungi, toxic plants or environmental pollution. Obesity is a risk factor for disease. For example, obesity in cats has mechanical and metabolic effects that increase the risk of several diseases, including diabetes mellitus, hepatic lipidosis, urinary tract disease and lameness (Tarkosova *et al*., 2016).

**Fig. 8.20E. Sheep showing signs of polioencephalomalacia (cerebrocortical necrosis), a nervous system disease associated with nutritional factors affecting the availability of thiamine (vitamin B1). (Courtesy of Dr Paula Menzies.)**

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## Appendix 8.4 Lameness in Farm and Companion Animals

### A8.4.1 Horses

Musculoskeletal injuries are common in horses (Holm and Foreman, 1996), especially in those used in sport (Clegg, 2011, 2012), and they are painful (Ashley *et al*., 2005). Foot pain is a common cause of lameness, including deep digital flexor tendonitis and lesions of the navicular bone (Dyson *et al*., 2005). Both horses and cattle (Hoblet and Weiss, 2001) can develop laminitis (Eades, 2010), which results in pathologic changes to the foot that cause severe discomfort, and inflammatory and neuropathic acute and chronic pain (Collins *et al*., 2010; Driessen *et al*., 2010). Osteoarthritis can develop in horses as a result of overuse and inappropriate mechanical force on the cartilage in joints. It develops as a result of inflammation of the components of the joint (synovial membrane, cartilage, joint capsule and subchondral bone), leading to degeneration of articular cartilage (Goodrich and Nixon, 2006).

### A8.4.2 Broilers

Lameness in broilers is multifactorial: there are genetic, environmental, nutritional and infectious components. Selection for rapid growth, greater body weight and increased breast muscle has affected broiler shape and walking ability, and increased mechanical stresses on legs and hip joints (Corr *et al.*, 2003a,b). Lame broilers lie down more, walk and feed less than non-lame broilers (Weeks *et al.*, 2000). Reduced time spent exercising by lame broilers and increased time resting increases susceptibility to leg weakness and contact dermatitis (hock burn and breast blisters from poor litter caused by chemical burning from ammonia). Factors associated with difficulty walking include age, genotype, type of feed, short dark periods, high stocking density and not using antibiotics (Knowles *et al.*, 2008). Lameness in poultry is often caused by infection in bone and joints (Butterworth, 1999), so effective prevention and control of viral and bacterial disease is essential on the farm and in the parent flock and hatchery. Common infectious disorders in poultry are osteomyelitis, chondritis and suppurative arthritis (Thorp, 1994). Acute arthritis is likely to be painful (Gentle, 2011). Tibial dyschondroplasia is a growth plate disorder that causes lameness, reduces dust bathing and increases the duration of tonic immobility (Vestergaard and Sanotra, 1999). However, the severity of tibial dyschondroplasia lesions is not always reflected in the gait score, possibly due to the limited innervation of the lesions and especially if complications such as distortion or fracture of the proximal tibia are not present (Garner *et al.*, 2002). Angular deformities of the long bones are frequently accompanied by slippage of the gastrocnemius tendon. Cartilage abnormalities increase the risk of injury and can act as foci for bacterial infections resulting in osteomyelitis. Necrosis and degeneration of cartilage and adjacent bone tissue in the proximal part of the tibia or femur (femoral head necrosis or proximal femoral degeneration) can occur (Waldenstedt, 2006; Packialakshmi *et al.*, 2015).

### A8.4.3 Dairy cattle

Most lameness in cattle (Figs 8.21E and 8.22E) originates from foot lesions (sole ulcer, white line disease, digital dermatitis and interdigital necrobacillosis) (Russell *et al.*, 1982; Whay *et al.*, 1998; Dyer *et al.*, 2007). The pain in the feet can be detected by the application of pressure using hoof testers (Dyer *et al.*, 2007), and lame cows can show hyperalgesia (Whay *et al.*, 1997, 1998). Cows with sole ulcers and interdigital necrobacillosis have identifiable changes in their gait/locomotion score (Flower and Weary, 2006; Tadich *et al.*, 2010). Cows with sole ulcer and white line disease can still show hyperalgesia 4 weeks after treatment, whereas those treated for acute digital infections (Whay *et al.*, 1998) or those given an NSAID (Whay *et al.*, 2005) show improvement sooner. Bruijnis *et al.* (2012) attempted to assess the welfare impact of different types of clinical foot lesions at a herd level by using expert assessment of the impact on locomotion to assess the severity of pain and then multiplying this by the duration and incidence of each condition. The welfare impact of digital dermatitis ranked highest, followed by sole ulcer, interdigital dermatitis and heel erosion, sole haemorrhage, white line disease, interdigital hyperplasia and interdigital foot rot. At the cow level (where only pain severity and duration were considered), the welfare impact was similar for all lesions, except for interdigital foot rot, which was scored very low. Digital dermatitis ranked highest, followed by interdigital dermatitis and heel erosion, interdigital hyperplasia, sole haemorrhage, white line disease and sole ulcer.

**Fig. 8.21E. Lame cull dairy cow with extensive swelling of a foot.**

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**Fig. 8.22E. Lame cull dairy cow.**

http://www.cabi.org/openresources/90202

Pain reduction in lame cows following either the use of a local anaesthetic nerve block to the feet or administration of an NSAID can improve gait score and reduce weight shifting between legs, but the effects are not dramatic (Rushen *et al.*, 2007; Flower *et al.*, 2008; Chapinal *et al.*, 2010). These modest effects were likely due to variation between the different causes of lameness and/or the increased sensitivity to pain that occurs during chronic lameness (Shearer *et al.*, 2013). Lameness can reduce food intake (Norring *et al.*, 2014) and increase lying behaviour (Ito *et al.*, 2010). Prompt treatment of lame cows is an important factor in reducing lameness prevalence (Barker *et al.*, 2010). However, the treatment of dairy cows by lateral restraint and claw trimming is stressful (raised blood cortisol concentration and leg movements), and a greater response seen in those lame due to sole ulcer or white line disease may be due to pain following the removal of inflamed corium (Janßen *et al.*, 2016). Other treatment options include reducing weight on the lesion by the application of a foot block to the healthy claw, analgesia and moving the cow to pasture or a sick pen (Shearer *et al.*, 2013). There are many environmental, genetic and nutritional predisposing factors for lameness in dairy cattle (Shearer *et al.*, 2013). For example, reduced lying duration, duration of housing and the types of surfaces on which cattle walk and stand (Barker *et al.*, 2007, 2010; Cook and Nordlund, 2009) are important factors. Gait scoring by external observers has shown that farmers tend to underestimate the prevalence of lameness on their farm (Leach *et al.*, 2010a). The main motivating factors that stimulate farmers to control lameness are pride in their herd, empathy for lame cows, economic losses and public image. Failure of farm accreditation and relative performance compared with other farmers were not considered to be important (Leach *et al.*, 2010b).

After the feet, the joints are the second most common site for causing lameness in cattle. Although the joints can be affected by trauma and developmental conditions (osteochondrosis), bacterial arthritis is more common (Nichols and Lardé, 2014). Bacteria can enter the joints from trauma, adjacent infection or septicaemia. In young calves, a common route of infection is via the umbilicus (Desrochers and Francoz, 2014). Although cattle can develop bursitis, these lesions do not normally cause lameness, but if the swelling is severe and associated with ulceration, they are likely to cause discomfort (Potterton *et al.*, 2011) (Fig. 8.23E).

**Fig. 8.23E. Veal calf with ulcerated bursitis lesion.**

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## A8.4.4 Sheep

Sheep are susceptible to bacterial foot lameness (foot rot, Fig. 8.24E; and foot scald, Fig. 8.25E) that varies from mild inflammation of the interdigital space to severe under-running and separation of the sole and hoof wall, exposure of underlying sensitive tissues and abscess development (Winter, 2008; Bennett and Hickford, 2011) (Fig. 8.26E). The severity of foot-rot lesions affects the ability of the sheep to walk, as shown by locomotion scoring (Kaler *et al.*, 2011). The pain from foot rot lesions is thought to be responsible for the raised plasma cortisol (Ley *et al.*, 1994) and catecholamine concentrations (Ley *et al.*, 1992) that can be found in sheep with these lesions. The scoring of sheep facial expressions that are thought to be indicative of pain is higher in sheep with foot rot than in non-lame sheep without lesions, and these scores are lower after treatment with antibiotics and an NSAID (McLennan *et al.*, 2016). Sheep can also experience lameness due to joint infections (Scott and Sargison, 2012).

**Fig. 8.24E. Foot rot lesion in a sheep. (Courtesy of Dr Paula Menzies.)**

http://www.cabi.org/openresources/90202

**Fig. 8.25E. Foot scald lesion in a sheep. (Courtesy of Dr Paula Menzies.)**

http://www.cabi.org/openresources/90202

**Fig. 8.26E. Lameness in a ram showing characteristic kneeling posture to graze. (Courtesy of Dr Paula Menzies.)**

http://www.cabi.org/openresources/90202

## A8.4.5 Pigs

In sows, lameness can be caused by osteochondrosis, arthritis, abscesses, claw lesions, overgrown claws and leg injuries (Heinonen *et al.*, 2006; Nalon *et al.*, 2013a). Lame sows can show increased sensitivity to mechanical pressure (hyperalgesia) on the affected limb (Nalon *et al.*, 2013b). Sows with overgrown hooves spend less time standing after feeding (Fitzgerald *et al.*, 2012), and growing pigs can have reduced feed intake when lame (Munsterhjelm *et al.*, 2015). In young, lame pigs with arthritis, analgesia improves their gait and activity

(Meijer *et al.*, 2015). In growing pigs, osteochondrosis dissecans and infectious arthritis are considered to be the most painful types of lameness (Jensen *et al.*, 2012). In growing pigs, but not in gilts and sows, the severity of calluses, bursitis and capped hock lesions are related to locomotion score (Kilbride *et al.*, 2009). In housed pigs, rough concrete floors and slatted or slotted floors with sharp edges can damage feet and legs, resulting in pain and possibly secondary bacterial infection (Sainsbury, 1998; Heinonen *et al.*, 2006; Kilbride *et al.*, 2009). Secondary infection can spread up the leg from foot lesions to cause tenosynovitis and cellulitis.

### A8.4.6 Dogs and cats

In dogs, the pain associated with lameness can affect their ability to perform normal behaviour and their mobility (Hudson *et al.*, 2004). In cats, osteoarthritis is a painful degenerative condition. It is recognized clinically by pain on palpation and/or manipulation, by thickening of individual joints and by characteristic radiographic changes. In addition to lameness, it can cause difficulty in jumping, climbing stairs and resentment of handling. NSAIDs can improve activity, mobility and interaction with the owner (Bennett and Morton, 2009; Slingerland *et al.*, 2011).

## Appendix 8.5 Measurement of Disease

Measurement of disease should form part of a welfare assessment of a unit or system. When assessing the welfare relevance of disease and injury, it is important to consider the epidemiology of the condition, the length of time that the animal has been suffering and any treatment or prevention that has been undertaken. The prevalence of a disease is the proportion of animals affected with a disease at any one time. The incidence of a disease is the number of new cases per population at risk that occur in a given period (Thrusfield, 2007). Surveys of disease prevalence are subject to various types of bias, and care is required in their conduct and interpretation (Bartlett *et al.*, 2010). Mortality rates are obviously a relatively crude measurement of health and welfare status. However, morbidity (amount of disease) and mortality rates are useful to assess poor welfare associated with disease and lack of care. Although they cannot be used exclusively as an indication of welfare (Ortiz-Pelaez *et al.*, 2008), morbidity and mortality are useful outcome measurements to identify management risk factors that affect health; for example, see the study on dairy heifers by Johnson *et al.* (2011). There are different views on the relevance of longevity to animal welfare (Bruijnis *et al.*, 2013), but if death is quick and without suffering it is not considered a welfare issue; however, when it is prolonged and associated with feelings such as sickness, pain and fear, it is a welfare concern (Broom, 1988). In livestock farming, mortality can be confounded with culling, so different criteria for culling influence the incidence of mortality. Depending on the condition, some animals with signs of disease will die suddenly on the farm, others will be euthanized, some will be sent to slaughter and others will remain in the herd (Jensen *et al.*, 2010). Culling is the selection (often on the basis of inferior quality or performance) and subsequent removal or killing of surplus animals from an animal population. The decision to cull an animal depends on many factors:

- animal factors, such as age, production, health status and reproductive performance; or
- economic factors, such as product price, the price of culled animals, and the price and availability of replacement animals (Bascom and Young, 1998).

Economic and production influences on the timing of culling of animals with disease can affect the risk of suffering (Langford and Stott, 2012). Ideally, mortality and culling rate should be low, as this would indicate that the animals were healthy and productive. However, in situations where the animals experience health problems associated with suffering, humane on-site euthanasia is an option consistent with good welfare (Morrow *et al.*, 2006).

Many diseases with a known cause can be diagnosed precisely by clinical signs, laboratory tests and other clinical procedures. The reliability of measurements of disease is dependent on factors such as the clinical skill of the observer, the validity of the diagnostic procedures undertaken and the accuracy and consistency of records. As part of a brief welfare assessment, it might be possible to make some general observations of the animals for signs of ill health, and more detailed studies can describe the severity of clinical signs or lesions by defining categories according to specified criteria. For example, in dairy cattle, coughing, coat condition (hair loss, dullness), skin condition, swellings, ulceration, claw condition, body condition and locomotion scores have been used (Whay *et al.*, 2003). The physiological effects of disease can be measured, and the severity of clinical signs can be scored by reference to photographs and by written description. For example, see Poulsen and McGuirk (2009) in relation to respiratory disease in cattle and Angell *et al.* (2015) for contagious ovine digital dermatitis. In addition, inspection of records for the following is beneficial in obtaining an impression of current and past health problems on a unit: treatment of clinical conditions; drugs used (bottles and containers, sale receipts and medicine records, Scott *et al.*, 2007); dystocia; sudden death; casualty slaughter; and culling and pathology identified post-mortem at the slaughterhouse (Main *et al.*, 2001; Whay, 2007; Leruste *et al.*, 2012; Knage-Rasmussen *et al.*, 2015). For example, in culled sows, common lesions found at the slaughterhouse were abscesses at various sites and skin surface injuries from bite wounds or trauma. Some sows were identified with chronic arthritis, decubital ulcers, healed fractures and osteomyelitis (Cleveland-Nielsen *et al.*, 2004). Although there are many other factors that can affect production and fertility, examination of these records might also provide evidence of the potential effects of disease on productivity (Smith, 1998; Edwards, 2007; De Vries *et al.*, 2011).

## Appendix 8.6 Disease Recognition

Within the EU, livestock farmers have to manage their animals by conforming to detailed legal requirements (European Council, 1998). Animals must be cared for by a sufficient number of staff who possess the appropriate ability, knowledge and professional competence. Coleman and Hemsworth (2014) reviewed the factors affecting the performance of stockpeople.

All animals kept in husbandry systems in which their welfare depends on frequent human attention should be inspected at least once a day. Animals in other systems, such as sheep in extensive systems, should be inspected at intervals sufficient to avoid any suffering. Adequate lighting is necessary so that the animals can be thoroughly inspected at any time. All stock-keepers should be familiar with normal behaviour and should watch for any signs of distress or disease. To do this, it is important that stock-keepers have enough time: to inspect the stock; to check equipment; and to take action to deal with any problem. The stock-keeper should be aware of the signs of ill health in the relevant species. Examples of signs of ill health are shown in Table 8.4.

**Table 8.4.** Examples of signs of ill health.

| |
|---|
| Listlessness |
| Separation from the group |
| Unusual behaviour (Fig. 8.27E) |
| Lack of co-ordination |
| Loss of body condition |
| Loss of appetite |
| Change in water consumption |
| Sudden fall in production, such as milk yield or egg production or quality |
| Constipation or diarrhoea (Fig. 8.28E) |
| Discharge from the nostrils (Fig. 8.29E) or eyes |
| Excessive saliva |
| Lack of rumination |
| Vomiting |
| Persistent coughing or sneezing |
| Rapid or irregular breathing |
| Abnormal resting behaviour |
| Difficulty moving (assessed using a locomotion score) or lameness |
| Swollen joints or navel |
| Mastitis |
| Visible wounds, abscesses or injuries |
| Scratching or rubbing |
| Shivering |
| Discoloration or blistering of the skin |

**Fig. 8.27E. Sick sheep showing signs associated with pneumonia. (Courtesy of Dr Paula Menzies.)**

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**Fig. 8.28E. Veal calf with diarrhoea.**

http://www.cabi.org/openresources/90202

**Fig. 8.29E. Calf with nasal discharge.**

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Sensors can now be used for electronic identification and data collection to monitor the health of individual and groups of animals (Rutten *et al*., 2013; Theurer *et al*., 2013). Sensors located on or in animals can be used to monitor a range of variables, including location, behaviour, locomotion, body temperature (Timsit *et al*., 2011) and rumen acidity (Falk *et al*., 2016). This information can then be transmitted and interpreted by software to recognize signs of disease. Groups of animals can be monitored for sound to indicate signs of disease such as coughing, and visual analysis can be used to assess the distribution of flocks of chickens to indicate abnormal behaviour (Berckmans, 2014). Thermography could be used to detect animals with fever (Schaefer *et al*., 2012). Milk can be monitored for indicators of mastitis, such as changes in yield (Huybrechts *et al*., 2014), electrical conductivity and somatic cell count (Kamphuis *et al*., 2016), and also potentially for hyperketonaemia (Denis-Robichaud *et al*., 2014). Lameness can be identified using accelerometers and pressure-sensitive platforms (Schlageter-Tello *et al*., 2014). Individual feed intake, proximity to a feeder (Wolfger *et al*., 2015) and live weight can be monitored. However, for disease identification, automatic sensors should be used to supplement rather than to replace inspection by stockpeople.

**References:** Agunos, A., Carson, C. and Léger, D. (2013) Review article: Antimicrobial therapy of selected diseases in turkeys, laying hens, and minor poultry species in Canada. *Canadian Veterinary Journal* 54, 1041–1052. http://dx.doi.org/10.1016/S0169-409X(02)00074-1

Alarcon, P., Wieland, B., Mateus, A.L.P. and Dewberry, C. (2014) Pig farmers' perceptions, attitudes, influences and management of information in the decision-making process for disease control. *Preventive Veterinary Medicine; Special Issue: SVEPM 2013 – A Truly Global Conference 2013 Society of Veterinary Epidemiology and Preventive Medicine Conference* 116, 223–242. http://dx.doi.org/10.1016/j.prevetmed.2013.08.004

Alban, L. and Agger, J.F. (1996) Welfare in Danish dairy herds: 1. Disease management routines in 1983 and 1994. *Acta Veterinaria Scandinavica* 37, 49–63.

Anderson, J., Baron, M., Cameron, A., Kock, R., Jones, B. *et al.* (2011) Rinderpest eradicated; what next? *Veterinary Record* 169, 10–11. http://dx.doi.org/10-11. 10.1136/vr.d4011

Angell, J.W., Blundell, R., Grove-White, D. and Duncan, J.S. (2015) Clinical and radiographic features of contagious ovine digital dermatitis and a novel lesion grading system. *Veterinary Record* 176, 544. http://dx.doi.org/10.1136/vr.102978

Asher, L., Diesel, G., Summers, J.F., McGreevy, P.D. and Collins, L.M. (2009) Inherited defects in pedigree dogs. Part 1: Disorders related to breed standards. *Veterinary Journal* 182, 402–411. http://dx.doi.org/10.1016/j.tvjl.2009.08.033

Ashley, F.H., Waterman-Pearson, A.E. and Whay, H.R. (2005) Behavioural assessment of pain in horses and donkeys: application to clinical practice and future studies. *Equine Veterinary Journal* 37, 565–575. http://dx.doi.org/10.1016/10.2746/042516405775314826

Ashley, P.J. (2007) Fish welfare: current issues in aquaculture. *Applied Animal Behaviour Science* 104, 199–235. http://dx.doi.org/10.1016/j.applanim.2006.09.001

Baarsch, M.J., Foss, D.L. and Murtaugh, M.P. (2000) Pathophysiologic correlates of acute porcine pleuropneumonia. *American Journal of Veterinary Research* 61, 684–690. http://doi.org/10.2460/ajvr.2000.61.684

Ballou, M.A., Cobb, C.J., Hulbert, L.E. and Carroll, J.A. (2011) Effects of intravenous *Escherichia coli* dose on the pathophysiological response of colostrum-fed Jersey calves. *Veterinary Immunology and Immunopathology* 141, 76–83. http://dx.doi.org/10.1016/j.vetimm.2011.02.008

Banting, A., Banting, S., Heinonen, K. and Mustonen, K. (2008) Efficacy of oral and parenteral ketoprofen in lactating cows with endotoxin-induced acute mastitis. *Veterinary Record* 163, 506–509. http://doi.org/10.1136/vr.163.17.506

Barber, I. (2007) Parasites, behaviour and welfare in fish. *Applied Animal Behaviour Science* 104, 251–264. http://dx.doi.org/10.1016/j.applanim.2006.09.005

Barker, Z.E., Amory, J.R., Wright, J.L., Blowey, R.W. and Green, L.E. (2007) Management factors associated with impaired locomotion in dairy cows in England and Wales. *Journal of Dairy Science* 90, 3270–3277. http://dx.doi.org/10.3168/jds.2006-176

Barker, Z.E., Leach, K.A., Whay, H.R., Bell, N.J. and Main, D.C.J. (2010) Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. *Journal of Dairy Science* 93, 932–941. http://dx.doi.org/10.3168/jds.2009-2309

Bartlett, P.C., Van Buren, J.W., Neterer, M. and Zhou, C. (2010) Disease surveillance and referral bias in the veterinary medical database. *Preventive Veterinary Medicine* 94, 264–271. http://dx.doi.org/10.1016/j.prevetmed.2010.01.007

Bascom, S.S. and Young, A.J. (1998) A summary of the reasons why farmers cull cows. *Journal of Dairy Science* 81, 2299–2305. http://doi.org/10.3168/jds.s0022-0302(98)75810-2

Bennett, D. and Morton, C. (2009) A study of owner observed behavioural and lifestyle changes in cats with musculoskeletal disease before and after analgesic therapy. *Journal of Feline Medicine and Surgery* 11, 997–1004. http://doi.org/10.1016/j.jfms.2009.09.016

Bennett, G.N. and Hickford, J.G.H. (2011) Ovine footrot: new approaches to an old disease. *Veterinary Microbiology* 148, 1–7. http://dx.doi.org/10.1016/j.vetmic.2010.09.003

Bennett, R. (2012) Economic rationale for interventions to control livestock disease. *Eurochoices* 11, 5–11. http://dx.doi.org/10.1111/j.1746-692X.2012.00227.x

Berckmans, D. (2014) Precision livestock farming technologies for welfare management in intensive livestock systems. *Revue Scientifique et Technique – Office International Des Épizooties* 33, 189–196. http://doi.org/10.20506/rst.33.1.2273

Berg, C. (2012) The need for monitoring farm animal welfare during mass killing for disease eradication purposes. *Animal Welfare* 21, 357–361. http://doi.org/10.7120/09627286.21.3.357

Berry, D.P., Bermingham, M.L., Good, M. and More, S.J. (2011) Genetics of animal health and disease in cattle. *Irish Veterinary Journal* 64, 5. http://dx.doi.org/10.1186/2046-0481-64-5

Bishop, S.C. and Woolliams, J.A. (2014) Genomics and disease resistance studies in livestock. *Livestock Science* 166, 190–198. https://doi.org/10.1016/j.livsci.2014.04.034

Broom, D.M. (1988) The scientific assessment of poor welfare. *Applied Animal Behaviour Science* 20, 5–19. http://dx.doi.org/10.1016/0168-1591(88)90122-0

Bruijnis, M.R.N., Beerda, B., Hogeveen, H. and Stassen, E.N. (2012) Assessing the welfare impact of foot disorders in dairy cattle by a modeling approach. *Animal* 6, 962–970. http://dx.doi.org/10.1017/S1751731111002606

Bruijnis, M.R.N., Meijboom, F.L.B. and Stassen, E.N. (2013) Longevity as an animal welfare issue applied to the case of foot disorders in dairy cattle. *Journal of Agricultural and Environmental Ethics* 26, 191–205. http://dx.doi.org/10.1007/s10806-012-9376-0

Butterworth, A. (1999) Infectious components of broiler lameness: a review. *Worlds Poultry Science Journal* 55, 327–352. http://doi.org/10.1079/wps19990024

Bywater, R.J. and Logan, E.F. (1974) The site and characteristics of intestinal water and electrolyte loss in *Escherichia coli* – induced diarrhoea in calves. *Journal of Comparative Pathology* 84, 599–610. http://dx.doi.org/10.1016/0021-9975(74)90051-6

Catanzaro, A., della Roca, G., Di Salvo, A. and Goldberg, M.E. (2015) Medical abdominal visceral pain in dogs. *American Journal of Animal and Veterinary Sciences* 10, 67–76. http://doi.org/10.3844/ajavsp.2015.67.76

Chapinal, N., de Passillé, A.M., Rushen, J. and Wagner, S. (2010) Automated methods for detecting lameness and measuring analgesia in dairy cattle. *Journal of Dairy Science* 93, 2007–2013. http://dx.doi.org/10.3168/jds.2009-2803

Chapinal, N., Fitzpatrick, C.E., Leslie, K.E. and Wagner, S.A. (2013) Short communication: experimentally induced mastitis reduces weight shifting between the rear legs while standing in dairy cows. *Journal of Dairy Science* 96, 3039–3043. http://dx.doi.org/10.3168/jds.2012-6397

Cheng, K.J., McAllister, T.A., Popp, J.D., Hristov, A.N., Mir, Z. and Shin, H.T. (1998) A review of bloat in feedlot cattle. *Journal of Animal Science* 76, 299–308. http://doi.org/10.2527/1998.761299x

Cheville, N.F. (2006) *Introduction to Veterinary Pathology*. Blackwell Publishing, Ames, Iowa.

Clegg, P.D. (2011) Musculoskeletal disease and injury, now and in the future. Part 1: Fractures and fatalities. *Equine Veterinary Journal* 43, 643–649. http://dx.doi.org/10.1111/j.2042-3306.2011.00457.x

Clegg, P.D. (2012) Musculoskeletal disease and injury, now and in the future. Part 2: Tendon and ligament injuries. *Equine Veterinary Journal* 44, 371–375. http://dx.doi.org/10.1111/j.2042-3306.2012.00563.x

Cleveland-Nielsen, A., Christensen, G. and Ersboll, A.K. (2004) Prevalences of welfare-related lesions at post-mortem meat-inspection in Danish sows. *Preventive Veterinary Medicine* 64, 123–131. http://dx.doi.org/10.1016/j.prevetmed.2004.05.003

Colditz, I.G. (2003) Metabolic effects of host defence responses during gastrointestinal parasitism in sheep. *Australian Journal of Experimental Agriculture* 43, 1437–1443. http://dx.doi.org/10.1071/EA03006

Colditz, I.G., Walkden-Brown, S., Daly, B.L. and Crook, B.J. (2005) Some physiological responses associated with reduced wool growth during blowfly strike in merino sheep. *Australian Veterinary Journal* 83, 695–699. http://doi.org/10.1111/j.1751-0813.2005.tb13053.x

Coleman, G.J. and Hemsworth, P.H. (2014) Training to improve stockperson beliefs and behaviour towards livestock enhances welfare and productivity. *Revue Scientifique et Technique – Office International des Épizooties* 33, 131–137. http://doi.org/10.20506/rst.33.1.2257

Collins, L.M., Asher, L., Summers, J.F., Diesel, G. and McGreevy, P.D. (2010) Welfare epidemiology as a tool to assess the welfare impact of inherited defects on the pedigree dog population. *Animal Welfare* 19(S1), 67–75. Available at: http://www.ingentaconnect.com/content/ufaw/aw/010/00000019/A00102s1/art00009 (accessed 3 December 2017).

Cook, N.B. and Nordlund, K.V. (2009) The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. *Veterinary Journal* 179, 360–369. http://dx.doi.org/10.1016/j.tvjl.2007.09.016

Corke, M.J. and Broom, D.M. (1999) The behaviour of sheep with sheep scab, *Psoroptes ovis* infestation. *Veterinary Parasitology* 83, 291–300. http://dx.doi.org/10.1016/S0304-4017(99)00065-5

Corr, S.A., Gentle, M.J., McCorquodale, C.C. and Bennett, D. (2003a) The effect of morphology on the musculoskeletal system of the modern broiler. *Animal Welfare* 12, 145–157. Available at: http://www.ingentaconnect.com/content/ufaw/aw/2003/00000012/00000002/art00001 (accessed 3 December 2017).

Corr, S.A., Gentle, M.J., McCorquodale, C.C. and Bennett, D. (2003b) The effect of morphology on walking ability in the modern broiler: a gait analysis study. *Animal Welfare* 12, 159–171. Available at: http://www.ingentaconnect.com/content/ufaw/aw/2003/00000012/00000002/art00002 (accessed 3 December 2017).

Crispin, S.M., Roger, P.A., O'Hare, H. and Binns, S.H. (2002) The 2001 foot and mouth disease epidemic in the United Kingdom: animal welfare perspectives. *Revue Scientifique et Technique de L'Office International des Épizooties* 21, 877–883. http://doi.org/10.20506/rst.21.3.1380

Cyples, J.A., Fitzpatrick, C.E., Leslie, K.E., Devries, T.J., Haley, D.B. and Chapinal, N. (2012) Short communication: The effects of experimentally induced *Escherichia coli* clinical mastitis on lying behavior of dairy cows. *Journal of Dairy Science* 95, 2571–2575. http://doi.org/10.3168/jds.2011-5135

David, B., Moe, R.O., Michel, V., Lund, V. and Mejdell, C. (2015a) Air quality in alternative housing systems may have an impact on laying hen welfare. Part I, Dust. *Animals* 5, 495–511. http://doi.org/10.3390/ani5030368

David, B., Mejdell, C., Michel, V., Lund, V. and Moe, R.O. (2015b) Air quality in alternative housing systems may have an impact on laying hen welfare. Part II, Ammonia. *Animals* 5, 886–896. http://dx.doi.org/10.3390/ani5030389

Dehove, A., Commault, J., Petitclerc, M., Teissier, M. and Macé, J. (2012) Economic analysis and costing of animal health: a literature review of methods and importance. *Revue Scientifique et Technique – Office International des Épizooties* 31, 591–617. http://doi.org/10.20506/rst.31.2.2146

Denis-Robichaud, J., Dubuc, J., Lefebvre, D. and DesCôteaux, L. (2014) Accuracy of milk ketone bodies from flow-injection analysis for the diagnosis of hyperketonemia in dairy cows. *Journal of Dairy Science* 97, 3364–3370. http://dx.doi.org/10.3168/jds.2013-6744

Desrochers, A. and Francoz, D. (2014) Clinical management of septic arthritis in cattle. *Veterinary Clinics of North America – Food Animal Practice* 30, 55–76. http://dx.doi.org/10.1016/j.cvfa.2013.11.006

de La Rocque, S., Balenghien, T., Halos, L., Dietze, K., Claes, F. *et al.* (2011) A review of trends in the distribution of vector-borne diseases: Is international trade contributing to their spread? *Revue Scientifique et Technique – Office International des Épizooties* 30, 119–130. http://dx.doi.org/10.20506/rst.issue.30.1.46

De Vries, M., Bokkers, E.A.M., Dijkstra, T., van Schaik, G. and de Boer, I.J.M. (2011) Invited review: Associations between variables of routine herd data and dairy cattle welfare indicators. *Journal of Dairy Science* 94, 3213–3228. http://dx.doi.org/10.3168/jds.2011-4169

Dietert, R.R., Golemboski, K.A. and Austic, R.E. (1994) Environment–immune interactions. *Poultry Science* 73, 1062–1076. http://doi.org/10.3382/ps.0731062

Dohms, J.E. and Saif, Y.M. (1984) Criteria for evaluating immunosuppression. *Avian Diseases* 28, 305–310. http://doi.org/10.2307/1590336

Driessen, B., Bauquier, S.H. and Zarucco, L. (2010) Neuropathic pain management in chronic laminitis. *Veterinary Clinics of North America – Equine Practice* 26, 315–337. http://dx.doi.org/10.1016/j.cveq.2010.04.002

Dyer, R.M., Neerchal, N.K., Tasch, U., Wu, Y., Dyer, P. and Rajkondawar, P.G. (2007) Objective determination of claw pain and its relationship to limb locomotion score in dairy cattle. *Journal of Dairy Science* 90, 4592–4602. http://dx.doi.org/10.3168/jds.2007-0006

Dyson, S.J., Murray, R. and Schramme, M.C. (2005) Lameness associated with foot pain: results of magnetic resonance imaging in 199 horses (January 2001–December 2003) and response to treatment. *Equine Veterinary Journal* 37, 113–121. https://doi.org/10.2746/0425164054223804

Eades, S.C. (2010) Overview of what we know about the pathophysiology of laminitis. *Journal of Equine Veterinary Science* 30, 83–86. http://dx.doi.org/10.1016/j.jevs.2010.01.047

East, I.J., Roche, S.E., Wicks, R.M., de Witte, K. and Garner, M.G. (2014) Options for managing animal welfare on intensive pig farms confined by movement restrictions during an outbreak of foot and mouth disease. *Preventive Veterinary Medicine* 117, 533–541. http://dx.doi.org/10.1016/j.prevetmed.2014.10.002

Edwards, S.A. (2007) Experimental welfare assessment and on-farm application. *Animal Welfare* 16, 111–115. http://www.ingentaconnect.com/content/ufaw/aw/2007/00000016/00000002/art00003

Edwards, S., Mejer, H., Roepstorff, A. and Prunier, A. (2014) Animal health, welfare and production problems in organic pregnant and lactating sows. *Organic Agriculture* 4, 93–105. http://doi.org/10.1007/s13165-014-0061-7

European Commission (2007) *A New Animal Health Strategy for the European Union (2007–2013) Where 'Prevention is Better than Cure'*. Office for Official Publications of the European Communities, Luxembourg. Available at: http://www.oie.int/fileadmin/Home/eng/Support_to_OIE_Members/docs/pdf/EU_Animal_Health_Strategy__EN_.pdf (accessed 3 December 2017).

European Council (1998) Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes. *Official Journal of the European Union* L221, 23–27. Available at: http://data.europa.eu/eli/dir/1998/58/oj (accessed 3 December 2017).

Falk, M., Münger, A. and Dohme-Meier, F. (2016) Technical note: A comparison of reticular and ruminal pH monitored continuously with 2 measurement systems at different weeks of early lactation. *Journal of Dairy Science* 99, 1951–1955. http://dx.doi.org/10.3168/jds.2015-9725

Fèvre, E.M., Bronsvoort, B.M.d.C., Hamilton, K.A. and Cleaveland, S. (2006) Animal movements and the spread of infectious diseases. *Trends in Microbiology* 14, 125–131. http://dx.doi.org/10.1016/j.tim.2006.01.004

Fitzgerald, R.F., Stalder, K.J., Karriker, L.A., Sadler, L.J., Hill, H.T. *et al.* (2012) The effect of hoof abnormalities on sow behavior and performance. *Livestock Science* 145, 230–238. http://dx.doi.org/10.1016/j.livsci.2012.02.009

Fitzpatrick, C.E., Chapinal, N., Petersson-Wolfe, C.S., DeVries, T.J., Kelton, D.F. *et al.* (2013) The effect of meloxicam on pain sensitivity, rumination time, and clinical signs in dairy cows with endotoxin-induced clinical mastitis. *Journal of Dairy Science* 96, 2847–2856. http://dx.doi.org/10.3168/jds.2012-5855

Fleming, M.W. (1997) Cortisol as an indicator of severity of parasitic infections of haemonchus contortus in lambs (*Ovis aries*). *Comparative Biochemistry and Physiology – B Biochemistry and Molecular Biology* 116, 41–44. http://doi.org/10.1016/s0305-0491(96)00157-5

Flower, F.C. and Weary, D.M. (2006) Effect of hoof pathologies on subjective assessments of dairy cow gait. *Journal of Dairy Science* 89, 139–146. https://doi.org/10.3168/jds.s0022-0302(06)72077-x

Flower, F.C., Sedlbauer, M., Carter, E., von Keyserlingk, M.A.G., Sanderson, D.J. and Weary, D.M. (2008) Analgesics improve the gait of lame dairy cattle. *Journal of Dairy Science* 91, 3010–3014. http://doi.org/10.3168/jds.2007-0968

Fogsgaard, K.K., Røntved, C.M., Sørensen, P. and Herskin, M.S. (2012) Sickness behavior in dairy cows during *Escherichia coli* mastitis. *Journal of Dairy Science* 95, 630–638. http://dx.doi.org/10.3168/jds.2011-4350

Fossum, O., Jansson, D.S., Etterlin, P.E. and Vagsholm, I. (2009) Causes of mortality in laying hens in different housing systems in 2001 to 2004. *Acta Veterinaria Scandinavica* 51, 1–28. http://doi.org/10.1186/1751-0147-51-3

Fox, S.M. (2012) Painful decisions for senior pets. *Veterinary Clinics of North America – Small Animal Practice* 42, 727–748. http://dx.doi.org/10.1016/j.cvsm.2012.04.010

Friton, G.M., Schmidt, H. and Schrödl, W. (2006) Clinical and anti-inflammatory effects of treating endotoxin-challenged pigs with meloxicam. *Veterinary Record* 159, 552–557. https://doi.org/10.1136/vr.159.17.552

Galvão, K.N., Flaminio, M.J.B.F., Brittin, S.B., Sper, R., Fraga, M. *et al.* (2010) Association between uterine disease and indicators of neutrophil and systemic energy status in lactating Holstein cows. *Journal of Dairy Science* 93, 2926–2937. https://doi.org/10.3168/jds.2009-2551

Garforth, C.J., Bailey, A.P. and Tranter, R.B. (2013) Farmers' attitudes to disease risk management in England: a comparative analysis of sheep and pig farmers. *Preventive Veterinary Medicine* 110, 456–466. https://doi.org/10.1016/j.prevetmed.2013.02.018

Garner, J.P., Falcone, C., Wakenell, P., Martin, M. and Mench, J.A. (2002) Reliability and validity of a modified gait scoring system and its use in assessing tibial dyschondroplasia in broilers. *British Poultry Science*, 43, 355–363. https://doi.org/10.1080/00071660120103620

Gaucher, M., Quessy, S., Letellier, A., Arsenault, J. and Boulianne, M. (2015) Impact of a drug-free program on broiler chicken growth performances, gut health, *Clostridium perfringens* and *Campylobacter jejuni* occurrences at the farm level. *Poultry Science* 94, 1791–1801. https://doi.org/10.3382/ps/pev142

Gavinelli, A., Kennedy, T. and Simonin, D. (2014) The application of humane slaughterhouse practices to large-scale culling. *OIE Revue Scientifique et Technique*, 33, 291–301. https://doi.org/10.20506/rst.33.1.2280

Gaynor, J.S. (2008) Control of cancer pain in veterinary patients. *Veterinary Clinics of North America: Small Animal Practice* 38, 1429–1448. https://doi.org/10.1016/j.cvsm.2008.06.009

Gentle, M.J. (2011) Pain issues in poultry. *Applied Animal Behaviour Science* 135, 252–258. https://doi.org/10.1016/j.applanim.2011.10.023

Gilbert, R.O. (2016) Management of reproductive disease in dairy cows. *Veterinary Clinics of North America: Food Animal Practice; Bovine Theriogenology* 32, 387–410. https://doi.org/10.1016/j.cvfa.2016.01.009

Gleeson, B.L. and Collins, A.M. (2015) Under what conditions is it possible to produce pigs without using antimicrobials? *Animal Production Science* 55, 1424–1431. https://doi.org/10.1071/an15271

Goodrich, L.R. and Nixon, A.J. (2006) Medical treatment of osteoarthritis in the horse – a review. *Veterinary Journal* 171, 51–69. https://doi.org/10.1016/j.tvjl.2004.07.008

Gocsik É., Kortes H. E., Oude Lansink, A. G. J. M. and Saatkamp H. W. (2014) Effects of different broiler production systems on health care costs in the Netherlands. *Poultry Science* 93, 1301–1317. https://doi.org/10.3382/ps.2013-03614

Goyena, E., Ruiz de Ybáñez, R., Martínez-Carrasco, C., Sáez-Acosta, A., Ramis, G. *et al.* (2015) Is *Sarcoptes scabiei* infection in pigs a major welfare concern? A quantitative assessment of its effect in the host's nocturnal rubbing and lying behavior. *Journal of Veterinary Behavior: Clinical Applications and Research* 10, 59–65. http://dx.doi.org/10.1016/j.jveb.2014.10.003

Green, L.E., Berriatua, E. and Morgan, K.L. (1997) The relationship between abnormalities detected in live lambs on farms and those detected at post mortem meat inspection. *Epidemiology and Infection* 118, 267–273. http://doi.org/10.1017/s0950268897007401

Gregory, N.G. and Wilkins, L.J. (1989) Broken bones in domestic fowl: handling and processing damage in end-of-lay battery hens. *British Poultry Science* 30, 555–582. http://doi.org/10.1080/00071668908417179

Gygax, M., Hirni, H., Zwahlen, R., Lazary, S. and Blum, J.W. (1993) Immune functions of veal calves fed low amounts of iron. *Journal of Veterinary Medicine Series A* 40, 345–358. http://doi.org/10.1111/j.1439-0442.1993.tb00638.x

Hamilton, T.D.C., Roe, J.M., Hayes, C.M., Jones, P., Pearson, G.R. and Webster, A.J.F. (1999) Contributory and exacerbating roles of gaseous ammonia and organic dust in the etiology of atrophic rhinitis. *Clinical and Diagnostic Laboratory Immunology* 6, 199–203. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC95687/ (accessed 3 December 2017).

Hammon, D.S., Evjen, I.M., Dhiman, T.R., Goff, J.P. and Walters, J.L. (2006) Neutrophil function and energy status in Holstein cows with uterine health disorders. *Veterinary Immunology and Immunopathology* 113, 21–29. http://dx.doi.org/10.1016/j.vetimm.2006.03.022

Hansen, B. (2000) Acute pain management. *Veterinary Clinics of North America: Small Animal Practice* 30, 899–916. http://dx.doi.org/10.1016/S0195-5616(08)70014-7

Heffernan, C., Nielsen, L., Thomson, K. and Gunn, G. (2008) An exploration of the drivers to bio-security collective action among a sample of UK cattle and sheep farmers. *Preventive Veterinary Medicine* 87, 358–372. http://dx.doi.org/10.1016/j.prevetmed.2008.05.007

Hein, W.R. and Harrison, G.B.L. (2005) Vaccines against veterinary helminths. *Veterinary Parasitology* 132, 217–222. http://dx.doi.org/10.1016/j.vetpar.2005.07.006

Heinonen, M., Oravainen, J., Orro, T., Seppä-Lassila, L., Ala-Kurikka, E. *et al.* (2006) Lameness and fertility of sows and gilts in randomly selected loose-housed herds in Finland. *Veterinary Record* 159, 383–387. http://doi.org/10.1136/vr.159.12.383

Hessing, M.J.C., Scheepens, C.J.M., Schouten, W.G.P., Tielen, M.J.M. and Wiepkema, P.R. (1994) Social rank and disease susceptibility in pigs. *Veterinary Immunology and Immunopathology* 43, 373–387. http://dx.doi.org/10.1016/0165-2427(94)90158-9

Hinchcliff, K.W., Rush, B.R. and Farris, J.W. (2005) Evaluation of plasma catecholamine and serum cortisol concentrations in horses with colic. *Journal of the American Veterinary Medical Association* 227, 276–280. http://dx.doi.org/10.2460/javma.2005.227.276

Hoareau, G.L., Jourdan, G., Mellema, M. and Verwaerde, P. (2012) Evaluation of arterial blood gases and arterial blood pressures in brachycephalic dogs. *Journal of Veterinary Internal Medicine* 26, 897–904. http://dx.doi.org/10.1111/j.1939-1676.2012.00941.x

Hoblet, K.H. and Weiss, W. (2001) Metabolic hoof horn disease. Claw horn disruption. *The Veterinary Clinics of North America: Food Animal Practice* 17, 111–127. https://doi.org/10.1016/s0749-0720(15)30057-8

Hoerr, F.J. (2010) Clinical aspects of immunosuppression in poultry. *Avian Diseases* 54, 2–15. http://doi.org/10.1637/8909-043009-review.1

Holm, A. and Foreman, J.H. (1996) Pathophysiology, diagnosis and treatment of common causes of lameness. *Pferdeheilkunde* 12, 575–580. http://dx.doi.org/10.21836/PEM19960448

Holmes, P.H. (1987) Pathophysiology of parasitic infections. *Parasitology* 94, S29–S51. http://doi.org/10.1017/s0031182000085814

Hovinen, M., Siivonen, J., Taponen, S., Hanninen, L., Pastell, M. *et al.* (2008) Detection of clinical mastitis with the help of a thermal camera. *Journal of Dairy Science* 91, 4592–4598. http://dx.doi.org/10.3168/jds.2008-1218

Hudson, J.T., Slater, M.R., Taylor, L., Scott, H.M. and Kerwin, S.C. (2004) Assessing repeatability and validity of a visual analogue scale questionnaire for use in assessing pain and lameness in dogs. *American Journal of Veterinary Research* 65, 1634–1643. http://dx.doi.org/10.2460/ajvr.2004.65.1634

Huff, G.R., Huff, W.E., Balog, J.M. and Rath, N.C. (2003) The effects of behavior and environmental enrichment on disease resistance of turkeys. *Brain, Behavior, and Immunity* 17, 339–349. http://dx.doi.org/10.1016/S0889-1591(03)00035-7

Huybrechts, T., Mertens, K., De Baerdemaeker, J., De Ketelaere, B. and Saeys, W. (2014) Early warnings from automatic milk yield monitoring with online synergistic control. *Journal of Dairy Science* 97, 3371–3381. http://dx.doi.org/10.3168/jds.2013-6913

Huzzey, J.M., Veira, D.M., Weary, D.M. and von Keyserlingk, M.A.G. (2007) Prepartum behavior and dry matter intake identify dairy cows at risk for metritis. *Journal of Dairy Science* 90, 3220–3233. http://dx.doi.org/1010.3168/jds.2006-807

Intraraksa Y., Engen R. L. and Switzer W. P. (1984) Pulmonary and hematologic changes in swine with *Mycoplasma hyopneumoniae* pneumonia. *American Journal of Veterinary Research* 45, 474–477.

Ito, K., von Keyserlingk, M.A.G., LeBlanc, S.J. and Weary, D.M. (2010) Lying behavior as an indicator of lameness in dairy cows. *Journal of Dairy Science* 93, 3553–3560. http://dx.doi.org/10.3168/jds.2009-2951

Janßen, S., Wunderlich, C., Heppelmann, M., Palme, R., Starke, A. *et al.* (2016) Short communication: pilot study on hormonal, metabolic, and behavioral stress response to treatment of claw horn lesions in acutely lame dairy cows. *Journal of Dairy Science* 99, 7481–7488. http://dx.doi.org/10.3168/jds.2015-10703

Jensen, T.B., Bonde, M.K., Kongsted, A.G., Toft, N. and Sørensen J.T. (2010) The interrelationships between clinical signs and their effect on involuntary culling among pregnant sows in group-housing systems. *Animal* 4, 1922–1928. http://dx.doi.org/10.1017/S1751731110001102

Jensen, T.B., Kristensen, H.H. and Toft, N. (2012) Quantifying the impact of lameness on welfare and profitability of finisher pigs using expert opinions. *Livestock Science* 149, 209–214. http://dx.doi.org/10.1016/j.livsci.2012.07.013

Johnson, K., Burn, C.C. and Wathes, D.C. (2011) Rates and risk factors for contagious disease and mortality in young dairy heifers. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 6, 1–10. http://dx.doi.org/10.1079/PAVSNNR20116059

Julian, R.J. (2000) Physiological, management and environmental triggers of the ascites syndrome: A review. *Avian Pathology* 29, 519–527. http://doi.org/10.1080/03079450020016751

Julian, R.J. (2005) Production and growth related disorders and other metabolic diseases of poultry – a review. *Veterinary Journal* 169, 350–369. http://dx.doi.org/10.1016/j.tvjl.2004.04.015

Kaler, J., George, T.R.N. and Green, L.E. (2011) Why are sheep lame? Temporal associations between severity of foot lesions and severity of lameness in 60 sheep. *Animal Welfare* 20, 433–438. Available at: http://www.ingentaconnect.com/content/ufaw/aw/2011/00000020/00000003/art00013 (accessed 3 December 2017).

Kamphuis, C., Dela Rue, B.T. and Eastwood, C.R. (2016) Field validation of protocols developed to evaluate in-line mastitis detection systems. *Journal of Dairy Science* 99, 1619–1631. http://dx.doi.org/10.3168/jds.2015-10253

Kanitz, E., Tuchscherer, M., Tuchscherer, A., Stabenow, B. and Manteuffel, G. (2002) Neuroendocrine and immune responses to acute endotoxemia in suckling and weaned piglets. *Biology of the Neonate* 81, 203–209. http://dx.doi.org/10.1159/000051535

Kaufmann-Bart, M. and Hoop, R.K. (2009) Diseases in chicks and laying hens during the first 12 years after battery cages were banned in Switzerland. *Veterinary Record.* 164, 203–207. http://doi.org/10.1136/vr.164.7.203

Kilbride, A., Gillman, C., Ossent, P. and Green, L. (2009) Impact of flooring on the health and welfare of pigs. *In Practice* 31, 390–395. http://doi.org/10.1136/inpract.31.8.390

Kilpinen, O., Roepstorff, A., Permin, A., Nørgaard-Nielsen, G., Lawson, L.G. and Simonsen, H.B. (2005) Influence of *Dermanyssus gallinae* and *Ascaridia galli* infections on behaviour and health of laying hens (*Gallus gallus domesticus*). *British Poultry Science* 46, 26–34. http://dx.doi.org/10.1080/00071660400023839

Knage-Rasmussen, K.M., Rousing, T., Sorensen, J.T. and Houe, H. (2015) Assessing animal welfare in sow herds using data on meat inspection, medication and mortality. *Animal* 9, 509–515. http://dx.doi.org/10.1017/S1751731114002705

Knowles, T.G., Kestin, S.C., Haslam, S.M., Brown, S.N., Green, L.E. *et al*. (2008) Leg disorders in broiler chickens: prevalence, risk factors and prevention. *PloS One* 3(2), e1545. http://dx.doi.org/10.1371/journal.pone.0001545

Kolkman, I., Aerts, S., Vervaecke, H., Vicca, J., Vandelook, J. *et al.* (2010a) Assessment of differences in some indicators of pain in double muscled Belgian Blue cows following naturally calving vs caesarean section. *Reproduction in Domestic Animals* 45, 160–167. http://dx.doi.org/10.1111/j.1439-0531.2008.01295.x

Kolkman, I., Opsomer, G., Aerts, S., Hoflack, G., Laevens, H. and Lips, D. (2010b) Analysis of body measurements of newborn purebred Belgian Blue calves. *Animal* 4, 661–671. http://dx.doi.org/10.1017/S1751731109991558

Kristensen, E. and Jakobsen, E.B. (2011a) Challenging the myth of the irrational dairy farmer: understanding decision-making related to herd health. *New Zealand Veterinary Journal* 59, 1–7. http://dx.doi.org/10.1080/00480169.2011.547162

Kristensen, E. and Jakobsen, E.B. (2011b) Danish dairy farmers' perception of biosecurity. *Preventive Veterinary Medicine* 99, 122–129. http://dx.doi.org/10.1016/j.prevetmed.2011.01.010

Kyriazakis, I., Tolkamp, B.J. and Hutchings, M.R. (1998) Towards a functional explanation for the occurrence of anorexia during parasitic infections. *Animal Behaviour* 56, 265–274. http://dx.doi.org/10.1006/anbe.1998.0761

Langford, F.M. and Stott, A.W. (2012) Culled early or culled late: economic decisions and risks to welfare in dairy cows. *Animal Welfare* 21(S1), 41–55. http://doi.org/10.7120/096272812x13345905673647

Larsen, L.E. (2000) Bovine respiratory syncytial virus (BRSV): a review. *Acta Veterinaria Scandinavica* 41, 1–24. http://www.ncbi.nlm.nih.gov/pubmed/10920473

Lay, D.C., Fulton, R.M., Hester, P.Y., Karcher, D.M., Kjaer, J.B., Mench, J.A., Mullens, B.A., Newberry, R.C., Nicol, C.J., O'Sullivan, N.P. and Porter, R.E. (2011) Hen welfare in different housing systems. *Poultry Science* 90, 278–294. http://dx.doi.org/10.3382/ps.2010-00962

Leach, K.A., Whay, H.R., Maggs, C.M., Barker, Z.E., Paul, E.S. *et al*. (2010a) Working towards a reduction in cattle lameness: 1. Understanding barriers to lameness control on dairy farms. *Research in Veterinary Science* 89, 311–317. http://dx.doi.org/10.1016/j.rvsc.2010.02.014

Leach, K.A., Whay, H.R., Maggs, C.M., Barker, Z.E., Paul, E.S. *et al*. (2010b) Working towards a reduction in cattle lameness: 2. Understanding dairy farmers' motivations. *Research in Veterinary Science* 89, 318–323. http://dx.doi.org/10.1016/j.rvsc.2010.02.017

Lean, I.J., Westwood, C.T. and Playford, M.C. (2008) Livestock disease threats associated with intensification of pastoral dairy farming. *New Zealand Veterinary Journal* 56, 261–269. http://dx.doi.org/10.1080/00480169.2008.36845

LeBlanc, S.J., Lissemore, K.D., Kelton, D.F., Duffield, T.F. and Leslie, K.E. (2006) Major advances in disease prevention in dairy cattle. *Journal of Dairy Science* 89, 1267–1279. http://doi.org/10.3168/jds.s0022-0302(06)72195-6

LeBlanc, S. (2010) Monitoring metabolic health of dairy cattle in the transition period. *Journal of Reproduction and Development* 56, S29–S35. http://dx.doi.org/10.1262/jrd.1056S29

Leruste, H., Brscic, M. Heutinck, L.F.M., Visser, E.K., Wolthuis-Fillerup, M. *et al.* (2012) The relationship between clinical signs of respiratory system disorders and lung lesions at slaughter in veal calves. *Preventive Veterinary Medicine* 105, 93–100. http://dx.doi.org/10.1016/j.prevetmed.2012.01.015

Leslie, K.E. and Petersson-Wolfe, C. (2012) Assessment and management of pain in dairy cows with clinical mastitis. *Veterinary Clinics of North America: Food Animal Practice* 28, 289–305. http://dx.doi.org/10.1016/j.cvfa.2012.04.002

Lester, P. and Gaynor, J.S. (2000) Management of cancer pain. *Veterinary Clinics of North America: Small Animal Practice* 30, 951–966. http://dx.doi.org/10.1016/S0195-5616(08)70017-2

Ley, S.J., Livingston, A. and Waterman, A.E. (1992) Effects of clinically occurring chronic lameness in sheep on the concentrations of plasma noradrenaline and adrenaline. *Research in Veterinary Science* 53, 122–125. http://doi.org/10.1016/0304-3959(89)90049-3

Ley, S.J., Waterman, A.E., Livingston, A. and Parkinson, T.J. (1994) Effect of chronic pain associated with lameness on plasma-cortisol concentrations in sheep – a field-study. *Research in Veterinary Science* 57, 332–335. http://doi.org/10.1016/0034-5288(94)90126-0

Lister, S. and van Nijhuis, B. (2012) The effects of alternative systems on disease and health of poultry. In: Sandilands, V. and Hocking, P. (eds) *Alternative Systems for Poultry: Health, Welfare and Productivity*. CAB International, Wallingford, UK, pp. 62–76. http://doi.org/10.1079/9781845938246.0062

Lohuis, J.A.C.M., Van Werven, T., Brand, A., Van Miert, A.S. J.P.A.M., Rohde, E. *et al.* (1991) Pharmacodynamics and pharmacokinetics of carprofen, a non-steroid anti-inflammatory drug, in healthy cows and cows with *Escherichia-coli* endotoxin-induced mastitis. *Journal of Veterinary Pharmacology and Therapeutics* 14, 219–229. http://dx.doi.org/10.1111/j.1365-2885.1991.tb00830.x

Lorenz, I., Mee, J.F., Earley, B. and More, S.J. (2011) Calf health from birth to weaning. I. General aspects of disease prevention. *Irish Veterinary Journal* 64, 10. http://dx.doi.org/10.1186/2046-0481-64-10

Main, D.C.J. and Mullan, S. (2012) Economic, education, encouragement and enforcement influences within farm assurance schemes. *Animal Welfare* 21, 107–111. http://dx.doi.org/10.7120/096272812X13345905673881

Main, D.C.J., Webster, A.J.F. and Green, L.E. (2001) Animal welfare assessment in farm assurance schemes. *Acta Agriculturae Scandinavica Section A – Animal Science* Supplement 30 51, 108–113. http://dx.doi.org/10.1080/090647001316923171

Main, D.C.J., Kent, J.P., Wemelsfelder, F., Ofner, E. and Tuyttens, F.A.M. (2003) Applications for methods of on-farm welfare assessment. *Animal Welfare* 12, 523–528. Available at: http://www.ingentaconnect.com/content/ufaw/aw/2003/00000012/00000004/art00011 (accessed 4 December 2017).

Mainau, E. and Manteca, X. (2011) Pain and discomfort caused by parturition in cows and sows. *Applied Animal Behaviour Science* 135, 241–251. http://dx.doi.org/10.1016/j.applanim.2011.10.020

Mannion, C., Lynch, P.B., Egan, J. and Leonard, F.C. (2007) Efficacy of cleaning and disinfection on pig farms in Ireland. *Veterinary Record* 161, 371–375. https://doi.org/10.1136/vr.161.11.371

Marley, C.L., Weller, R.F., Neale, M., Main, D.C.J., Roderick, S. and Keatinge, R. (2010) Aligning health and welfare principles and practice in organic dairy systems: A review. *Animal* 4, 259–271. http://dx.doi.org/10.1017/S1751731109991066

Marshall, B.M. and Levy, S.B. (2011) Food animals and antimicrobials: impacts on human health. *Clinical Microbiology Reviews* 24, 718–733. http://doi.org/10.1128/cmr.00002-11

Mathews, K.A. (2000) Pain assessment and general approach to management. *Veterinary Clinics of North America: Small Animal Practice* 30, 729–755. http://dx.doi.org/10.1016/S0195-5616(08)70004-4

Mathews, K.A. (2008) Neuropathic pain in dogs and cats: If only they could tell us if they hurt. *Veterinary Clinics of North America: Small Animal Practice* 38, 1365–1414. http://dx.doi.org/10.1016/j.cvsm.2008.09.001

Maunsell, F. and Donovan, G.A. (2008) Biosecurity and risk management for dairy replacements. *Veterinary Clinics of North America: Food Animal Practice* 24, 155–190. http://dx.doi.org/10.1016/j.cvfa.2007.10.007

McEwen, S.A. (2006) Antibiotic use in animal agriculture: What have we learned and where are we going? *Animal Biotechnology* 17, 239–250. http://dx.doi.org/10.1080/10495390600957233

McGuirk, B.J., Forsyth, R. and Dobson, H. (2007) Economic cost of difficult calvings in the United Kingdom dairy herd. *Veterinary Record* 161, 685–687. http://doi.org/10.1136/vr.161.20.685

McLennan, K.M., Rebelo, C.J.B., Corke, M.J., Holmes, M.A., Leach, M.C. and Constantino-Casas, F. (2016) Development of a facial expression scale using footrot and mastitis as models of pain in sheep. *Applied Animal Behaviour Science* 176, 19–26. http://dx.doi.org/10.1016/j.applanim.2016.01.007

McRae, K.M., Stear, M.J., Good, B. and Keane, O.M. (2015) The host immune response to gastrointestinal nematode infection in sheep. *Parasite Immunology* 37, 605–613. http://dx.doi.org/10.1111/pim.12290

Medrano-Galarza, C., Gibbons, J., Wagner, S., de Passille, A.M. and Rushen, J. (2012) Behavioral changes in dairy cows with mastitis. *Journal of Dairy Science* 95, 6994–7002. http://dx.doi.org/10.3168/jds.2011-5247

Mee, J.F., Geraghty, T., O'Neill, R. and More, S.J. (2012) Bioexclusion of diseases from dairy and beef farms: risks of introducing infectious agents and risk reduction strategies. *Veterinary Journal* 194, 143–150. http://dx.doi.org/10.1016/j.tvjl.2012.07.001

Meijer, E., van Nes, A., Back, W. and van der Staay, F.J. (2015) Clinical effects of buprenorphine on open field behaviour and gait symmetry in healthy and lame weaned piglets. *Veterinary Journal* 206, 298–303. http://dx.doi.org/10.1016/j.tvjl.2015.10.016

Mellor, D.J. and Stafford, K.J. (2004) Animal welfare implications of neonatal mortality and morbidity in farm animals. *Veterinary Journal* 168, 118–133. http://dx.doi.org/10.1016/j.tvjl.2003.08.004

Milne, C.E., Dalton, G.E. and Stott, A.W. (2008) Balancing the animal welfare, farm profitability, human health and environmental outcomes of sheep ectoparasite control in Scottish flocks. *Livestock Science* 118, 20–33. http://dx.doi.org/10.1016/j.livsci.2008.01.016

Moore, J.N. and Barton, M.H. (2003) Treatment of endotoxemia. *Veterinary Clinics of North America: Equine Practice* 19, 681–695. http://dx.doi.org/10.1016/j.cveq.2003.08.006

Morrow, W.E., Meyer, R.E., Roberts, J. and Lascelles, D. (2006) Financial and welfare implications of immediately euthanizing compromised nursery pigs. *Journal of Swine Health and Production* 14, 25–34. Available at: https://www.aasv.org/shap/issues/v14n1/v14n1p25.html (accessed 4 December 2017).

Munsterhjelm, C., Heinonen, M. and Valros, A. (2015) Effects of clinical lameness and tail biting lesions on voluntary feed intake in growing pigs. *Livestock Science* 181, 210–219. http://dx.doi.org/10.1016/j.livsci.2015.09.003

Muri, K., Leine, N. and Valle, P.S. (2016) Welfare effects of a disease eradication programme for dairy goats. *Animal* 10, 333–341. http://dx.doi.org/10.1017/S1751731115000762

Murray, C.F. and Leslie, K.E. (2013) Newborn calf vitality: risk factors, characteristics, assessment, resulting outcomes and strategies for improvement. *Veterinary Journal* 198, 322–328. http://dx.doi.org/10.1016/j.tvjl.2013.06.007

Nalon, E., Conte, S., Maes, D., Tuyttens, F.A.M. and Devillers, N. (2013a) Assessment of lameness and claw lesions in sows. *Livestock Science* 156, 10–23. http://dx.doi.org/10.1016/j.livsci.2013.06.003

Nalon, E., Maes, D., Piepers, S., van Riet, M.M.J., Janssens, G.P.J. *et al.* (2013b) Mechanical nociception thresholds in lame sows: evidence of hyperalgesia as measured by two different methods. *Veterinary Journal* 198, 386–390. http://dx.doi.org/10.1016/j.tvjl.2013.08.016

Nasr, M.A.F., Nicol, C.J. and Murrell, J.C. (2012) Do laying hens with keel bone fractures experience pain? *PloS One* 7, e42420. http://doi.org/10.1371/journal.pone.0042420

Newberry, R.C. (1995) Environmental enrichment – increasing the biological relevance of captive environments. *Applied Animal Behaviour Science* 44, 229–243. http://doi.org/10.1016/0168-1591(95)00616-z

Nichols, S. and Lardé, H. (2014) Noninfectious joint disease in cattle. *Veterinary Clinics of North America: Food Animal Practice; Bovine Orthopedics* 30, 205–223. http://dx.doi.org/10.1016/j.cvfa.2013.11.010

Niinistö, K.E., Korolainen, R.V., Raekallio, M.R., Mykkänen, A.K., Koho, N.M. *et al.* (2010) Plasma levels of heat shock protein 72 (HSP72) and β-endorphin as indicators of stress, pain and prognosis in horses with colic. *Veterinary Journal* 184, 100–104. http://doi.org/10.1016/j.tvjl.2009.01.011

Norring, M., Häggman, J., Simojoki, H., Tamminen, P., Winckler, C. and Pastell, M. (2014) Short communication: lameness impairs feeding behavior of dairy cows. *Journal of Dairy Science* 97, 4317–4321. http://dx.doi.org/10.3168/jds.2013-7512

OIE (World Organisation for Animal Health) (2016) Chapter 7.6: Killing of animals for disease control purposes. In: *Terrestrial Animal Health Code*. OIE (World Organisation for Animal Health), Paris. Available at: http://www.oie.int/international-standard-setting/terrestrial-code/access-online/ (accessed 4 December 2017).

Oltenacu, P.A. and Broom, D.M. (2010) The impact of genetic selection for increased milk yield on the welfare of dairy cows. *Animal Welfare* 19(S1), 39–49. Available at: http://www.ingentaconnect.com/content/ufaw/aw/2010/00000019/A00102s1/art00006 (accessed 4 December 2017).

Ortiz-Pelaez, A., Pritchard, D.G., Pfeiffer, D.U., Jones, E., Honeyman, P. and Mawdsley, J.J. (2008) Calf mortality as a welfare indicator on British cattle farms. *Veterinary Journal* 176, 177–181. http://dx.doi.org/10.1016/j.tvjl.2007.02.006

Packialakshmi, B., Rath, N.C., Huff, W.E. and Huff, G.R. (2015) Poultry femoral head separation and necrosis: a review. *Avian Diseases* 59, 349–354. http://dx.doi.org/10.1637/11082-040715-Review.1

Page, S.W. and Gautier, P. (2012) Use of antimicrobial agents in livestock. *Revue Scientifique et Technique – Office International des Épizooties* 31, 145–188. http://dx.doi.org/10.20506/rst.31.1.2106

Patel, J.R. and Heldens, J.G.M. (2009) Review of companion animal viral diseases and immunoprophylaxis. *Vaccine* 27, 491–504. http://dx.doi.org/10.1016/j.vaccine.2008.11.027

Patel, J.R., Heldens, J.G.M., Bakonyi, T. and Rusvai, M. (2012) Important mammalian veterinary viral immunodiseases and their control. *Vaccine* 30, 1767–1781. http://dx.doi.org/10.1016/j.vaccine.2012.01.014

Perry, B. and Grace, D. (2009) The impacts of livestock diseases and their control on growth and development processes that are pro-poor. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, 2643–2655. http://dx.doi.org/10.1098/rstb.2009.0097

Perry, B.D., Grace, D. and Sones, K. (2013) Current drivers and future directions of global livestock disease dynamics. *Proceedings of the National Academy of Sciences* 110, 20871–20877. http://doi.org/10.1073/pnas.1012953108

Pesavento, P.A. and Murphy, B.G. (2014) Common and emerging infectious diseases in the animal shelter. *Veterinary Pathology* 51, 478–491. http://doi.org/10.1177/0300985813511129

Phythian, C., Phillips, K., Wright, N. and Morgan, M. (2014) Sheep health, welfare and production planning 1. Recording and benchmarking performance indicators of flock health and production. *In Practice* 36, 85–92. http://dx.doi.org/10.1136/inp.g1197

Plant, J.W. (2006) Sheep ectoparasite control and animal welfare. *Small Ruminant Research* 62, 109–112. http://dx.doi.org/10.1016/j.smallrumres.2005.08.003

Plessers, E., Wyns, H., Watteyn, A., Pardon, B., De Backer, P. and Croubels, S. (2015) Characterization of an intravenous lipopolysaccharide inflammation model in calves with respect to the acute-phase response. *Veterinary Immunology and Immunopathology* 163, 46–56. http://dx.doi.org/10.1016/j.vetimm.2014.11.005

Pluske, J.R., Pethick, D.W., Hopwood, D.E. and Hampson, D.J. (2002) Nutritional influences on some major enteric bacterial diseases of pig. *Nutrition Research Reviews* 15, 333–371. http://dx.doi.org/10.1079/NRR200242

Potterton, S.L., Green, M.J., Millar, K.M., Brignell, C.J., Harris, J. *et al.* (2011) Prevalence and characterisation of, and producers' attitudes towards, hock lesions in UK dairy cattle. *Veterinary Record* 169, 634. http://dx.doi.org/10.1136/vr.d5491

Poulsen, K.P. and McGuirk, S.M. (2009) Respiratory disease of the bovine neonate. *Veterinary Clinics of North America: Food Animal Practice* 25, 121–137. http://dx.doi.org/10.1016/j.cvfa.2008.10.007

Prichard, R.K., Hennessy, D.R. and Griffiths, D.A. (1974) Endocrine responses of sheep to infection with *Trichostrongylus colubriformis*. *Research in Veterinary Science* 17, 182–187.

Prunier, A., Heinonen, M. and Quesnel, H. (2010) High physiological demands in intensively raised pigs: impact on health and welfare. *Animal* 4, 886–898. http://dx.doi.org/10.1017/S175173111000008X

Raj, M. (2008) Humane killing of nonhuman animals for disease control purposes. *Journal of Applied Animal Welfare Science* 11, 112–124. http://dx.doi.org/10.1080/10888700801925679

Rasmussen, D.B., Fogsgaard, K., Røntved, C.M., Klaas, I.C. and Herskin, M.S. (2011) Changes in thermal nociceptive responses in dairy cows following experimentally induced *Escherichia coli* mastitis. *Acta Veterinaria Scandinavica* 53, 32. http://dx.doi.org/10.1186/1751-0147-53-32

Rauw, W.M., Kanis, E., Noordhuizen-Stassen, E.N. and Grommers, F.J. (1998) Undesirable side effects of selection for high production efficiency in farm animals: a review. *Livestock Production Science* 56, 15–33. http://doi.org/10.1016/s0301-6226(98)00147-x

Reece, W.O. (1984) Response of anemic calves to exertion. *American Journal of Veterinary Research* 45, 437–439. Available at: https://www.ncbi.nlm.nih.gov/pubmed/6711970 (accessed 4 December 2017).

Reece, W.O. and Hotchkiss, D.K. (1987) Blood studies and performance among calves reared by different methods 1.

*Journal of Dairy Science* 70, 1601–1611. http://dx.doi.org/10.3168/jds.S0022-0302(87)80188-1

Rees, G. (2016) Postpartum emergencies in cows. *In Practice* 38, 23–31. http://dx.doi.org/10.1136/inp.h6407

Reeves, D.E. (2006) Maximizing herd health. *Animal Biotechnology* 17, 177–187. http://dx.doi.org/10.1080/10495390600962134

Refsdal, A.O. (2000) To treat or not to treat: a proper use of hormones and antibiotics. *Animal Reproduction Science* 60, 109–119. http://doi.org/10.1016/s0378-4320(00)00094-4

Reiner, G. (2009) Investigations on genetic disease resistance in swine – a contribution to the reduction of pain, suffering and damage in farm animals. *Applied Animal Behaviour Science; Special Issue: Animal Suffering and Welfare* 118, 217–221. http://doi.org/10.1016/j.applanim.2009.02.011

Reiner, G., Hübner, K. and Hepp, S. (2009) Suffering in diseased pigs as expressed by behavioural, clinical and clinical-chemical traits, in a well-defined parasite model. *Applied Animal Behaviour Science* 118, 222–231. http://doi.org/10.1016/j.applanim.2009.02.010

Richens, I.F., Hobson-West, P., Brennan, M.L., Hood, Z., Kaler, J. *et al.* (2016) Factors influencing veterinary surgeons' decision-making about dairy cattle vaccination. *Veterinary Record* 179, 410. http://doi.org/10.1136/vr.103822

Riddell, C., Helmbold, C.F., Singsen, E.P. and Matterson, L.D. (1968) Bone pathology of birds affected with cage layer fatigue. *Avian Diseases* 12, 285–297.

Robertson, J.F., Wilson, D. and Smith, W.J. (1990) Atrophic rhinitis: the influence of the aerial environment. *Animal Production* 50, 173–182. http://doi.org/10.1017/s0003356100004578

Robinson, N.J., Brennan, M.L., Cobb, M. and Dean, R.S. (2016) Investigating preventive-medicine consultations in first-opinion small-animal practice in the United Kingdom using direct observation. *Preventive Veterinary Medicine* 124, 69–77. http://dx.doi.org/10.1016/j.prevetmed.2015.12.010

Roedler, F.S., Pohl, S. and Oechtering, G.U. (2013) How does severe brachycephaly affect dog's lives? Results of a structured preoperative owner questionnaire. *Veterinary Journal* 198, 606–610. http://dx.doi.org/10.1016/j.tvjl.2013.09.009

Rollin, B.E. (2009) Veterinary ethics and production diseases. *Animal Health Research Reviews* 10, 125–130. http://doi.org/10.1017/s1466252309990168

Rooney, N.J. and Sargan, D.R. (2010) Welfare concerns associated with pedigree dog breeding in the UK. *Animal Welfare* 19(S1), 133–140. Available at: http://www.ingentaconnect.com/content/ufaw/aw/2010/00000019/A00102s1/art00017 (accessed 4 December 2017).

Rushen, J., Pombourcq, E. and de Passillé, A.M. (2007) Validation of two measures of lameness in dairy cows. *Applied Animal Behaviour Science* 106, 173–177. http://dx.doi.org/10.1016/j.applanim.2006.07.001

Russell, A.M., Rowlands, G.J., Shaw, S.R. and Weaver, A.D. (1982) Survey of lameness in British dairy cattle. *Veterinary Record* 111, 155–160. http://doi.org/10.1136/vr.111.8.155

Rutten, C.J., Velthuis, A.G.J., Steeneveld, W. and Hogeveen, H. (2013) Invited review: Sensors to support health management on dairy farms. *Journal of Dairy Science* 96, 1928–1952. http://dx.doi.org/10.3168/jds.2012-6107

Sainsbury, D. (1998) *Animal Health: Health, Disease, and Welfare of Farm Livestock*. Blackwell Science, Oxford.

Sangster, N.C. (2001) Managing parasiticide resistance. *Veterinary Parasitology* 98, 89–109. http://dx.doi.org/10.1016/S0304-4017(01)00425-3

Schaefer, A.L., Cook, N.J., Bench, C., Chabot, J.B., Colyn, J. *et al*. (2012) The non-invasive and automated detection of bovine respiratory disease onset in receiver calves using infrared thermography. *Research in Veterinary Science* 93, 928–935. http://dx.doi.org/10.1016/j.rvsc.2011.09.021

Schiffman, J.D. and Breen, M. (2015) Comparative oncology: What dogs and other species can teach us about humans with cancer. *Philosophical Transactions of the Royal Society B: Biological Sciences* 370, 20140231. http://dx.doi.org/10.1098/rstb.2014.0231

Schlageter-Tello, A., Bokkers, E.A.M., Koerkamp, P.W.G.G., Van Hertem, T., Viazzi, S. *et al.* (2014) Manual and automatic locomotion scoring systems in dairy cows: a review. *Preventive Veterinary Medicine* 116, 12–25. http://dx.doi.org/10.1016/j.prevetmed.2014.06.006

Scott, P.R. (2005) The management and welfare of some common ovine obstetrical problems in the United Kingdom. *Veterinary Journal* 170, 33–40. http://dx.doi.org/10.1016/j.tvjl.2004.03.010

Scott, P.R. and Sargison, N.D. (2012) Diagnosis and treatment of joint infections in 39 adult sheep. *Small Ruminant Research* 106, 16–20. http://doi.org/10.1016/j.smallrumres.2011.09.013

Scott, P.R., Sargison, N.D. and Wilson, D.J. (2007) The potential for improving welfare standards and productivity in United Kingdom sheep flocks using veterinary flock health plans. *Veterinary Journal* 173, 522–531. http://dx.doi.org/10.1016/j.tvjl.2006.02.007

Seixas, F., Palmeira, C., Pires, M.A., Bento, M.J. and Lopes, C. (2011) Grade is an independent prognostic factor for feline mammary carcinomas: a clinicopathological and survival analysis. *Veterinary Journal* 187, 65–71. http://dx.doi.org/10.1016/j.tvjl.2009.10.030

Sepúlveda-Varas, P., Proudfoot, K.L., Weary, D.M. and von Keyserlingk, M.A.G. (2016) Changes in behaviour of dairy cows with clinical mastitis. *Applied Animal Behaviour Science: Behavioural Indicators of Health* 175, 8–13. http://dx.doi.org/10.1016/j.applanim.2014.09.022

Shearer, J.K., Stock, M.L., Van Amstel, S.R. and Coetzee, J.F. (2013) Assessment and management of pain associated with lameness in cattle. *Veterinary Clinics of North America: Food Animal Practice* 29, 135–156. http://dx.doi.org/10.1016/j.cvfa.2012.11.012

Shini, S., Huff, G.R., Shini, A. and Kaiser, P. (2010) Understanding stress-induced immunosuppression: exploration of cytokine and chemokine gene profiles in chicken peripheral leukocytes. *Poultry Science* 89, 841–851. http://doi.org/10.3382/ps.2009-00483

Siekkinen, K.-M., Heikkilä, J., Tammiranta, N. and Rosengren, H. (2012) Measuring the costs of biosecurity on poultry farms: a case study in broiler production in Finland. *Acta Veterinaria Scandinavica* 54, 12. http://dx.doi.org/10.1186/1751-0147-54-12

Sleeckx, N., de Rooster, H., Veldhuis Kroeze, E.J.B., van Ginneken, C. and van Brantegem, L. (2011) Canine mammary tumours, an overview. *Reproduction in Domestic Animals* 46, 1112–1131. http://dx.doi.org/10.1111/j.1439-0531.2011.01816.x

Slingerland, L.I., Hazewinkel, H.A.W., Meij, B.P., Picavet, P. and Voorhout, G. (2011) Cross-sectional study of the prevalence and clinical features of osteoarthritis in 100 cats. *Veterinary Journal* 187, 304–309. http://dx.doi.org/10.1016/j.tvjl.2009.12.014

Smith, H., Jones, T.C. and Hunt, R.D. (1972) *Veterinary Pathology*. Lea and Febiger, Philadelphia, Pennsylvania.

Smith, M.T., Bennett, A.M., Grubman, M.J. and Bundy, B.C. (2014) Foot-and-mouth disease: technical and political challenges to eradication. *Vaccine* 32, 3902–3908. http://dx.doi.org/10.1016/j.vaccine.2014.04.038

Smith, R.A. (1998) Impact of disease on feedlot performance: a review. *Journal of Animal Science* 76, 272–274. http://doi.org/10.2527/1998.761272x

Snyder, J.R. (1989) The pathophysiology of intestinal damage: effects of luminal distention and ischemia. *The Veterinary Clinics of North America: Equine Practice* 5, 247–270. https://www.ncbi.nlm.nih.gov/pubmed/2670106

Ssematimba, A., Hagenaars, T.J., de Wit, J.J., Ruiterkamp, F., Fabri, T.H. *et al.* (2013) Avian influenza transmission risks: analysis of biosecurity measures and contact structure in Dutch poultry farming. *Preventive Veterinary Medicine* 109, 106–115. https://doi.org/10.1016/j.prevetmed.2012.09.001

Stafford, K. (2006) *The Welfare of Dogs*. Springer, Dordrecht, the Netherlands. http://dx.doi.org/10.1007/978-1-4020-4362-8

Stärk, K.D.C. (1999) The role of infectious aerosols in disease transmission in pigs. *Veterinary Journal* 158, 164–181. http://dx.doi.org/10.1053/tvjl.1998.0346

Stärk, K.D.C. (2000) Epidemiological investigation of the influence of environmental risk factors on respiratory diseases in Swine – a literature review. *The Veterinary Journal* 159, 37–56. http://dx.doi.org/10.1053/tvjl.1999.0421

Tadich, N., Flor, E. and Green, L. (2010) Associations between hoof lesions and locomotion score in 1098 unsound dairy cows. *The Veterinary Journal* 184, 60–65. http://dx.doi.org/10.1016/j.tvjl.2009.01.005

Tarkosova, D., Story, M.M., Rand, J.S. and Svoboda, M. (2016) Feline obesity – prevalence, risk factors, pathogenesis, associated conditions and assessment: a review. *Veterinarni Medicina* 61, 295–307. http://dx.doi.org/10.17221/145/2015-VETMED

Taylor, J.D., Fulton, R.W., Lehenbauer, T.W., Step, D.L. and Confer, A.W. (2010) The epidemiology of bovine respiratory disease: What is the evidence for predisposing factors? *Canadian Veterinary Journal* 51, 1095–1102. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2942046/ (accessed 4 December 2017).

Theurer, M.E., Amrine, D.E. and White, B.J. (2013) Remote noninvasive assessment of pain and health status in cattle. *Veterinary Clinics of North America: Food Animal Practice* 29, 59–74. http://dx.doi.org/10.1016/j.cvfa.2012.11.011

Thiermann, A.B. (2004) The OIE process, procedures and international relations. *Global Conference on Animal Welfare: An OIE Initiative, Proceedings*, Paris, 23–25 February 2004. OIE, Paris/European Commission, Luxembourg, pp. 7–12. http://animal-welfare.oie.in

Thoefner, M.B., Ersboll, B.K., Jansson, N. and Hesselholt, M. (2003) Diagnostic decision rule for support in clinical assessment of the need for surgical intervention in horses with acute abdominal pain. *Canadian Journal of Veterinary Research – Revue Canadienne De Recherche Veterinaire* 67, 20–29. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC227023/

Thorp, B.H. (1994) Skeletal disorders in the fowl – a review. *Avian Pathology* 23, 203–236. http://dx.doi.org/10.1080/03079459408418991

Thrusfield, M. (2007) *Veterinary Epidemiology*. Blackwell, Oxford.

Timsit, E., Assié, S., Quiniou, R., Seegers, H. and Bareille, N. (2011) Early detection of bovine respiratory disease in young bulls using reticulo-rumen temperature boluses. *The Veterinary Journal* 190, 136–142. http://dx.doi.org/10.1016/j.tvjl.2010.09.012

Toma, L., Stott, A.W., Heffernan, C., Ringrose, S. and Gunn, G.J. (2013) Determinants of biosecurity behaviour of British cattle and sheep farmers – a behavioural economics analysis. *Preventive Veterinary Medicine* 108, 321–333. https://doi.org/10.1016/j.prevetmed.2012.11.009

Tuchscherer, M., Kanitz, E., Puppe, B. and Tuchscherer, A. (2006) Early social isolation alters behavioral and physiological responses to an endotoxin challenge in piglets. *Hormones and Behavior* 50, 753–761. http://dx.doi.org/10.1016/j.yhbeh.2006.06.026

Valeeva, N.I., Lam, T.J.G.M. and Hogeveen, H. (2007) Motivation of dairy farmers to improve mastitis management. *Journal of Dairy Science* 90, 4466–4477. http://dx.doi.org/10.3168/jds.2007-0095

Vangroenweghe, F., Duchateau, L., Boutet, P., Lekeux, P., Rainard, P. *et al.* (2005) Effect of carprofen treatment following experimentally induced *Escherichia coli* mastitis in primiparous cows. *Journal of Dairy Science* 88, 2361–2376. http://doi.org/10.3168/jds.s0022-0302(05)72914-3

Verbrugghe, E., Boyen, F., Gaastra, W., Bekhuis, L., Leyman, B. *et al.* (2012) The complex interplay between stress and bacterial infections in animals. *Veterinary Microbiology* 155, 115–127. http://dx.doi.org/10.1016/j.vetmic.2011.09.012

Vestergaard, K.S. and Sanotra, G.S. (1999) Relationships between leg disorders and changes in the behaviour of broiler chickens. *Veterinary Record* 144, 205–209. http://doi.org/10.1136/vr.144.8.205

Waldenstedt, L. (2006) Nutritional factors of importance for optimal leg health in broilers: a review. *Animal Feed Science and Technology* 126, 291–307. http://dx.doi.org/10.1016/j.anifeedsci.2005.08.008

Wall, R. and Lovatt, F. (2015) Blowfly strike: biology, epidemiology and control. *In Practice* 37, 181–188. http://dx.doi.org/10.1136/inp.h1434

Wathes, C.M., Miller, B.G. and Bourne, F.J. (1989) Cold stress and post-weaning diarrhoea in piglets inoculated orally or by aerosol. *Animal Science* 49, 483–496. http://dx.doi.org/10.1017/S0003356100032694

Weaver, J., Leoan, E., Edan, M. and D'Alessio, F.D. (2012) Initial assessment of strategic plans for improving the performance of veterinary services in developing countries: a review of OIE PVS gap analysis reports. *Revue Scientifique et Technique – Office International des Épizooties*, 31, 631–645. http://doi.org/10.20506/rst.31.2.2144

Webster, A.B. (2004) Welfare implications of avian osteoporosis. *Poultry Science* 83, 184–192. https://doi.org/10.1093/ps/83.2.184

Webster, A.J.F. (1983) Environmental stress and the physiology, performance and health of ruminants. *Journal of Animal Science* 57, 1584–1593. https://doi.org/10.2527/jas1983.5761584x

Webster, A.J.F. (1992) Problems of feeding and housing: their diagnosis and control. In: Moss, R. (ed.) *Livestock Health and Welfare*. Longman Scientific and Technical, Harlow, Essex, UK, pp. 292–332.

Weeks, C.A., Danbury, T.D., Davies, H.C., Hunt, P. and Kestin, S.C. (2000) The behaviour of broiler chickens and its modification by lameness. *Applied Animal Behaviour Science* 67, 111–125. http://dx.doi.org/10.1016/S0168-1591(99)00102-1

Weeks, C.A., Lambton, S.L. and Williams, A.G. (2016) Implications for welfare, productivity and sustainability of the variation in reported levels of mortality for laying hen flocks kept in different housing systems: a meta-analysis of ten studies. *PloS One* 11, e0146394. https://doi.org/10.1371/journal.pone.0146394

Whay, H.R. (2007) The journey to animal welfare improvement. *Animal Welfare* 16, 117–122. Available at: http://www.ingentaconnect.com/content/ufaw/aw/2007/00000016/00000002/art00004 (accessed 4 December 2017).

Whay, H.R., Waterman, A.E. and Webster, A.J.F. (1997) Associations between locomotion, claw lesions and nociceptive threshold in dairy heifers during the peri-partum period. *Veterinary Journal* 154, 155–161.

Whay, H.R., Waterman, A.E., Webster, A.J.F. and O'Brien, J.K. (1998) The influence of lesion type on the duration of hyperalgesia associated with hindlimb lameness in dairy cattle. *Veterinary Journal* 156, 23–29. https://doi.org/10.1016/s1090-0233(97)80053-6

Whay, H.R., Main, D.C.J., Green, L.E. and Webster, A.J.F. (2003) Assessment of the welfare of dairy cattle using animal-based measurements: direct observations and investigation of farm records. *Veterinary Record* 153, 197–202. https://doi.org/10.1136/vr.153.7.197

Whay, H.R., Webster, A.J.F. and Waterman-Pearson, A.E. (2005) Role of ketoprofen in the modulation of hyperalgesia associated with lameness in dairy cattle. *Veterinary Record* 157, 729–733. http://doi.org/10.1136/vr.157.23.729

Whay, H.R., Barker, Z.E., Leach, K.A. and Main, D.C.J. (2012) Promoting farmer engagement and activity in the control of dairy cattle lameness. *Veterinary Journal* 193, 617–621. http://dx.doi.org/10.1016/j.tvjl.2012.06.041

Whitehead, C.C. (2004) Overview of bone biology in the egg-laying hen. *Poultry Science* 83, 193–199. http://doi.org/10.1093/ps/83.2.193

Whiting, T.L. (2003) Foreign animal disease outbreaks, the animal welfare implications for Canada: risks apparent from international experience. *Canadian Veterinary Journal – Revue Veterinaire Canadienne* 44, 805–815. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC340296/ (accessed 4 December 2017).

Wilkins, L.J., McKinstry, J.L., Avery, N.C., Knowles, T.G., Brown, S.N. *et al.* (2011) Influence of housing system and design on bone strength and keel bone fractures in laying hens. *Veterinary Record* 169, 414. https://doi.org/10.1136/vr.d4831

Williams, A.R. (2011) Immune-mediated pathology of nematode infection in sheep – is immunity beneficial to the animal? *Parasitology* 138, 547–556. http://dx.doi.org/10.1017/S0031182010001654

Wingfield, W.E., Cornelius, L.M. and Deyoung, D.W. (1974) Pathophysiology of the gastric dilation torsion complex in the dog. *Journal of Small Animal Practice* 15, 735–739. https://doi.org/10.1111/j.1748-5827.1974.tb05659.x

Winter, A.C. (2008) Lameness in sheep. *Small Ruminant Research* 76, 149–153. https://doi.org/10.1016/j.smallrumres.2007.12.008

Wolfger, B., Manns, B.J., Barkema, H.W., Schwartzkopf-Genswein, K., Dorin, C. and Orsel, K. (2015) Evaluating the cost implications of a radio frequency identification feeding system for early detection of bovine respiratory disease in feedlot cattle. *Preventive Veterinary Medicine* 118, 285–292. http://dx.doi.org/10.1016/j.prevetmed.2014.12.001

Woolliams, J.A., Lewis, T.W. and Blott, S.C. (2011) Canine hip and elbow dysplasia in UK Labrador Retrievers. *Veterinary Journal* 189, 169–176. http://dx.doi.org/10.1016/j.tvjl.2011.06.015

Wright, N., Meijboom, F.L.B. and Sandøe, P. (2010) Thoughts on the ethics of preventing and controlling epizootic diseases. *Veterinary Journal* 186, 127–128. http://dx.doi.org/10.1016/j.tvjl.2009.12.028

Yeiser, E.E., Leslie, K.E., McGilliard, M.L. and Petersson-Wolfe, C.S. (2012) The effects of experimentally induced *Escherichia coli* mastitis and flunixin meglumine administration on activity measures, feed intake, and milk parameters. *Journal of Dairy Science* 95, 4939–4949. http://dx.doi.org/10.3168/jds.2011-5064

Zepeda, C., Salman, M. and Ruppanner, R. (2001) International trade, animal health and veterinary epidemiology: challenges and opportunities. *Preventive Veterinary Medicine* 48, 261–271. http://doi.org/10.1016/s0167-5877(00)00200-2

Zimov, J.L., Botheras, N.A., Weiss, W.P. and Hogan, J.S. (2011) Associations among behavioral and acute physiologic responses to lipopolysaccharide-induced clinical mastitis in lactating dairy cows. *American Journal of Veterinary Research* 72, 620–627. http://dx.doi.org/10.2460/ajvr.72.5.620