Well-ventilated housing is essential for reducing levels of respiratory disease in sheep. This shed has an open central ridge, a low stocking rate, an open sheltered side and Yorkshire boarding on the more exposed side; there are also air inlets at either end, allowing good airflow throughout

Respiratory disease in sheep

2. Treatment and control

SUZANNA BELL

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RESPIRATORY disease can lead to severe financial losses and welfare implications in sheep flocks. Individual animals may be affected or outbreaks can occur, with losses due to mortality, reduced production – poor or delayed growth in fattening lambs with a greater feed consumption for finishing, and illthrift and poor milk production in adult ewes – and treatment costs. This article discusses how to reduce the impact of the condition in flocks and describes specific methods for the control and treatment of common pathogens. An article in the last issue (*In Practice*, April 2008, volume 30, pp 200-207) discussed the diagnosis of respiratory disease in sheep and its potential aetiologies.

INVESTIGATING THE CAUSE OF PNEUMONIA

The identification of predisposing factors and confirmation of the causal pathogens are key steps in designing a control programme for the successful treatment and management of respiratory disease in sheep, particularly when dealing with an outbreak (see Part 1).

The causes of pneumonia in sheep of any age can be broadly described as adverse physical and physiological stresses, combined with a viral, bacterial or parasitic infection. In addition, management factors associated with respiratory disease include:

- Overcrowding during housing;
- Poor ventilation during housing;
- Inadequate/heavily soiled bedding leading to high environmental ammonia levels and increased humidity;
- Recent handling;
- Transportation;
- Inadequate nutrition;
- Concurrent disease.

Natural factors that can predispose sheep to pneumonia include:

- Extremes in weather conditions/temperature, with both stress and relative humidity contributing;
- Breed/genetics;
- Gender (males are possibly more susceptible than females);
- Age (lambs are more susceptible than adults).

The prevention and control of pneumonia in sheep is therefore based on minimising these factors, combined with strategic prophylactic treatments or vaccinations to reduce the impact of the causal respiratory pathogens. The table above gives the normal findings in sheep undergoing clinical examination.

NORMAL PARAMETERS IN SHEEP

Heart rate	Adults: 60 to 120 beats per minute (average 75) Lambs: 120 to 160 beats per minute (average 140)
Respiratory rate	Varies with ambient temperature and age Adults: 12 to 72 breaths per minute (average 36) Lambs: 30 to 70 breaths per minute (average 50)
Rectal temperature	39°C
Respiratory sounds	Normal respiratory sounds are audible on thoracic auscultation during inspiration ventrally and over the large airways. Expiratory sounds are often also audible

LOWER RESPIRATORY TRACT DISEASE

BACTERIAL PNEUMONIA

Treatment of bacterial pneumonia is based on antimicrobial therapy; the products currently licensed for use in sheep are listed in the table on page 279. Confirmation of the organism involved allows the most appropriate antimicrobial to be selected. In severely affected cases, the use of a non-steroidal anti-inflammatory drug (NSAID) together with an antimicrobial can increase

treatment success. There are currently no licensed NSAIDs available for use in sheep, so these products must be used under the prescribing cascade (see table on the right).

Mannheimia/Pasteurella pneumonia

Mannheimia haemolytica is frequently involved in cases of acute pneumonia as a primary or secondary infection, so prevention and treatment focusing on this organism will often reduce losses.

Vaccination

Booster vaccination of ewes four to six weeks before lambing allows lambs to acquire antibody protection from colostrum for the first three to four weeks of life. The primary vaccination course consists of two injections four to six weeks apart, with protective antibody levels achieved two weeks after the second injection. Annual booster vaccinations are needed.

In flocks with *Mannheimia/Pasteurella* pneumonia, it may be necessary to vaccinate lambs from three weeks of age (the earliest age recommended by vaccine manufacturers). In some flocks, vaccination is carried out in animals as young as 10 days old, although there is a risk that reduced immunocompetence at this age may limit vaccine efficacy.

Lambs may need booster vaccinations at times of peak risk (eg, at weaning).

Treatment

One injection of long-acting oxytetracycline (20 mg/kg or 1 ml/kg of a 200 mg/ml solution intramuscularly) is usually effective in very early cases or for prophylactic treatment, and provides four days of cover. Some cases will need retreating after three to four days. Tilmicosin and penicillin-based antimicrobials can also be effective, although not all *Mannheimia/Pasteurella* strains are sensitive to penicillin. Trials using danofloxacin have suggested that this drug is effective for treating *Mannheimia/Pasteurella* infections, although it is not licensed for use in sheep (McKellar and others 1998, Aliabadi and others 2003)

The control and prevention of other respiratory pathogens can also reduce losses due to *Mannheimia/Pasteurella* pneumonia.

DRUGS FOR TREATING OVINE PNEUMONIA

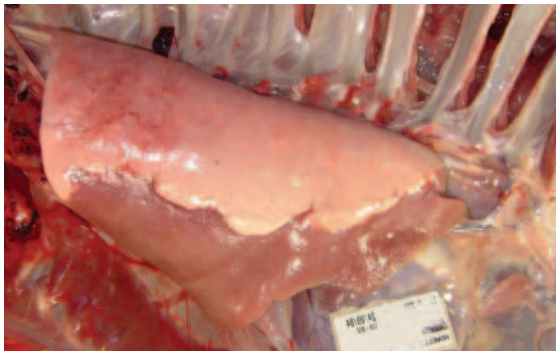
Licensed drugs	
Antimicrobials	Amoxicillin trihydrate Ampicillin trihydrate Procaine benzylpenicillin Procaine penicillin and dihydrostreptomycin sulfate Procaine penicillin and neomycin sulfate Oxytetracycline dihydrate/hydrochloride Tilmicosin (not for use in lambs weighing <15 kg)
Anthelmintics	Benzimidazoles (albendazole/ricobendazole, fenbendazole, oxfendazole, mebendazole) Levamisole Avermectins (ivermectin, doramectin) Avermectin/milbemycin (moxidectin) Closantel
Drugs used under the prescribing cascade	
Corticosteroids	
Non-steroidal anti-inflammatory drugs	Ketoprofen Meloxicam Carprofen Flunixin meglumine Tolfenamic acid
Licensed *Mannheimia/Pasteurella* vaccines	Ovipast Plus (Intervet UK)
Combined clostridial/*Pasteurella* vaccines	Heptavac P Plus (Intervet UK) Ovivac P Plus (Intervet UK)

Mycoplasma infections

Mycoplasma infections, typically caused by *Mycoplasma ovipneumoniae*, usually present as coughing in groups of lambs, with potentially reduced growth rates and an increased risk of a more severe secondary *M haemolytica* pneumonia.

Treatment

Mycoplasmas are sensitive to macrolide and newer fluoroquinolone antibiotics, and are potentially less sensitive to tetracyclines. However, evidence of macrolide antibiotic resistance has been demonstrated in some isolates. Recent studies to investigate the efficacy of fluoroquinolone antibiotics (eg, difloxacin and dano-



Typical lung consolidation caused by *Mycoplasma ovipneumoniae* in a lamb seen on postmortem examination. Picture, Rudolph Reichel

General recommendations for preventing outbreaks of pneumonia

Housed sheep

- Maximise fresh air. Avoid draughty or poorly ventilated barns
- Reduce the numbers of animals in the airspace and in groups
- Split groups of animals according to age, size and origin
- Avoid youngstock and older animals sharing the same airspace

All sheep

- Consider *Mannheimia/Pasteurella* vaccination to reduce potential losses due to a primary or secondary *Mannheimia/Pasteurella* infection
- Avoid exposed, wet and windy sites that induce stress and encourage crowding. Consider providing shelter or moving the group from an exposed area, although moving animals during an outbreak may exacerbate the problem
- Isolate purchased sheep before mixing with the home flock
- Avoid turning store lambs on to lush grass without prior *Mannheimia/Pasteurella* vaccination
- Introduce supplementary feeding gradually as sudden dietary changes can predispose lambs to outbreaks of pneumonia
- Minimise handling stress, such as shearing, transportation and co-mingling different groups, particularly at times of concurrent weather-induced stress
- Ensure the effective management of concurrent diseases such as parasitic gastroenteritis or tickborne fever
- Avoid malnutrition, which may predispose sheep to respiratory disease
- Administer prophylactic long-acting oxytetracycline if necessary. However, careful preventive management and the use of *Mannheimia/Pasteurella* vaccination is preferable, particularly with known high-risk groups such as bought-in animals or when moving groups (eg, store lambs during the autumn)

floxacin) against various respiratory pathogens in sheep, including *M ovipneumoniae*, have produced promising results (Mavrogianni and Fthenakis 2005), although these products are not licensed for use in this species.

VIRAL PNEUMONIA

As there is a lack of viral vaccines for use in sheep, control of viral pneumonia is based on reducing the predisposing factors and treating secondary bacterial infections. The involvement of respiratory viruses in natural cases of respiratory disease is largely unknown, with a combined bacterial and viral aetiology suggested in some outbreaks.

Parainfluenza virus type 3

The live attenuated cattle intranasal parainfluenza virus type 3 (PI3) vaccine has been used off-licence for vaccinating sheep in experimental studies and in the field to control PI3 infections in flocks with endemic respiratory disease problems (Davies and others 1980, Lehmkuhl and Cutlip 1985, Rodger 1989). Flock levels of PI3 infection have been reduced following the use of this vaccine in ewes, with the resultant protection appearing to last for one season only. There are concerns about using combined live PI3/infectious bovine rhinotracheitis (IBR) vaccines, however, as a latent IBR infection has subsequently developed in some vaccinated lambs (Lehmkuhl and Cutlip 1985).

Studies carried out using a killed intranasal vaccine have encountered hypersensitivity reactions in treated sheep, and experimental use of intramuscular injectable PI3 vaccines have given mixed results. Davies and others (1980) found that intramuscular injection of live PI3 appeared ineffective, whereas intranasal inoculation of live PI3 was highly effective, particularly for protection against a bacterial superinfection. Wells and others (1978) found that intramuscular formalin-inactivated PI3 antigen vaccination conferred protection against PI3 infection; however, reduced protection against bacterial superinfection was found with inactivated vaccines containing BRL 5097 double-stranded RNA when compared with the antigen-only inactivated vaccine.

Ovine adenovirus and respiratory syncytial virus

As little is known about the significance of these two viruses as a cause of naturally occurring pneumonia in sheep, limited emphasis has been placed on developing vaccines to prevent these viral infections. Inactivated and adsorbed ovine adenovirus vaccines have been found to provide good antibody responses in experimentally vaccinated lambs in Hungary (Pálfi and Belák 1980). Keles and others (1998) found that intranasal vaccination with inactivated respiratory syncytial virus reduced the magnitude and duration of nasal viral shedding and induced immune responses in vaccinated lambs.

Sheep housing

Ridged sheds

Natural shed ventilation depends on two effects: the stack (or pressure) effect and wind pressure.

Stack effect

The stack effect occurs when warm, stale air in the shed rises out through an open roof ridge, drawing fresh air in through side air inlets. Sheds up to 12 m wide require a roof ridge 0·3 m wide. Yards up to 24 m wide need a 0·6 m wide ridge. Capped ridges can be problematic in exposed sites, as rain can blow in underneath, leading to wet bedding. Downdraughts can be prevented by terminating open roof ridges short of the end walls. Wide-span sheds may need gaps up to 18 mm wide cut into the roof sheets to improve the upward airflow.

Wind pressure

Wind pressure ventilation systems make use of the differences in air pressure induced by wind movements in and out of the shed. High pressure-induced airflow pushes air in on the windward side of the shed and out on the leeward side, due to a relative low air pressure caused by the shed obstructing the wind.

In sheltered areas, the sides of the shed can be kept open. However, in more exposed areas, draught-protective walls (1·2 m high) may be needed.

Floor spacing

Minimum floor space for an average housed ewe on bedding should be approximately 1·5 m^2.

Suggested approximate floor spacing for specific sheep types are:

- Halfbred ewes: 1·4 m^2;
- Blackfaced ewes: 1·1 m^2;
- Weaned lambs: 0·8 m^2.

Ventilation

To prevent respiratory disease, effective ventilation should:

- Reduce air humidity;
- Increase the oxygen:carbon dioxide ratio;
- Reduce the aerosolised microorganism concentration;
- Reduce airborne dust levels;
- Reduce noxious gas levels, such as ammonia, hydrogen sulphide and methane.

Open-sided sheds allow good airflow in sheltered locations. Yorkshire boarding or webbing may be needed in more exposed sites

PARASITIC PNEUMONIA

Lungworm

The most clinically significant lungworm in sheep is *Dictyocaulus filaria*; the other two potentially pathogenic worms are *Protostrongylus rufescens* and *Muellerius capillaris*, both of which can occasionally produce mild clinical signs.

Infestation of pasture with *Dictyocaulus* species larvae is at its greatest between September and November in the UK, with clinical cases tending to occur between June and November. Clinical disease is controlled by treating the group with an anthelmintic and moving animals to clean pasture. In most flocks, anthelmintics used for the routine treatment of parasitic gastroenteritis also effectively control lungworm. Avoiding pasture that was used for sheep grazing the previous year will help to prevent exposure to high levels of lungworm larvae carried over from the previous season.

Protostrongylus and *Muellerius* worms both have a mollusc intermediate host that requires wet ground for survival. Therefore, sheep exposure is determined by the distribution of the infected snails.

Treatment

Dictyocaulus, *Protostrongylus* and *Muellerius* worms are all responsive to benzimidazole, levamisole and avermectin anthelmintics. Treatment with levamisole may need to be repeated after two weeks as this drug has a limited efficacy against the larval stages of worms. Morantel has no therapeutic action against lungworm.

Ivermectin, doramectin and moxidectin are believed to have a potential persistent activity of four weeks or more against *D filaria* worms in sheep, although studies carried out have specifically examined the treatment efficacy and persistent activity against the cattle lungworm *Dictyocaulus viviparus*.

CHRONIC PNEUMONIA

The effective prevention and treatment of acute pneumonia will, in many cases, inevitably reduce the impact and incidence of chronic pneumonia in flocks, including the incidence of lung abscesses caused by opportunistic bacteria. Some chronic lung infections, however, are caused by specific agents or are initiated by particular management factors, and these are discussed below.

Chronic respiratory viruses

Maedi-visna

Maedi-visna is caused by a lentiviral infection and has a long latent period, so detection of the disease often occurs some time after it has entered a flock. The interval between introduction of infection and the detection of maedi-visna in a flock can be 10 years, by which time a high proportion of the animals is likely to be seropositive. Clinical disease is usually not evident until at least 50 per cent of the flock is sero-

Yorkshire space boarding or polyvinyl chloride webbing can provide protection against driving rain and strong winds. Sliding panels can be used to increase ventilation on still days.

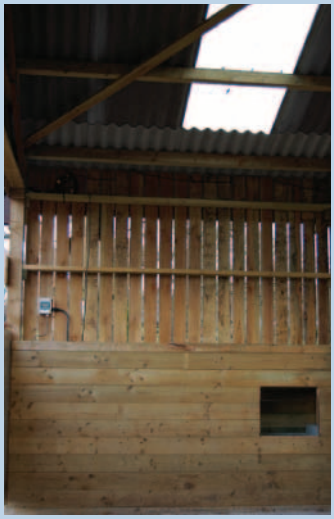
Monopitch sheds

Monopitch sheds are open-fronted yards that allow good ventilation without draughts at animal level when there is low air movement. Stocking rates, however, should be kept low, and if the building is more than 10 m wide, ventilation openings are needed in the back wall.

Other housing

Other types of housing, such as old-style farm buildings, may need to be adapted using the above general principles. In some cases, fans or artificial ventilation systems may have to be installed to improve the overall ventilation.

Yorkshire boarding can be used to allow good ventilation while blocking driving rain in exposed sites



(right) The solid lower wall prevents draughts at animal level, with Yorkshire boarding above to provide a fresh air inlet. (below) An open ridge enables the warm, stale air to escape and allows the circulation of fresh air in ridged buildings

Control of maedi-visna

For eradication

- Test and cull seropositive animals every six to 12 months
- Remove lambs born to seropositive ewes from the flock
- Snatch lambs at birth and artificially rear them to develop a 'clean' flock. Strict segregation of this flock is vital due to possible transmission from environmental contamination. A low level of intrauterine transmission is thought to occur, although this appears to be rare
- Purchase replacement animals from maedi-visna-free accredited flocks

To reduce transmission

- Increase the flock replacement rate to maintain a young flock, and only retain replacement ewe lambs from young ewes
- Do not keep ewes that are more than four to five years of age
- Avoid pooling colostrum in endemic flocks as this can spread the virus

positive. Many infected sheep remain asymptomatic for life, with only approximately 25 to 30 per cent of them developing clinical signs. In a heavily infected flock, 50 per cent of naive sheep will seroconvert within nine months of entering the group. In endemic flocks, the seroprevalence increases with age, with 25 per cent of ewes seropositive at two years of age and 90 per cent seropositive at five years of age or older. The disease is often less obvious in lowland flocks on a high plane of nutrition.

The methods chosen for maedi-visna control in infected flocks will be influenced by factors such as the farm layout, resources, the type and value of the sheep involved and whether economics lend to eradication or the reduction of transmission (see box above).

The maedi-visna accreditation scheme, run by the Scottish Agricultural College, comprises member flocks that are proven free of maedi-visna infection following regular serological screening. Membership of the scheme also requires flocks to meet specific management requirements. A maedi-visna monitoring scheme is available to carry out regular serological screening for flocks in which the segregation required for the accreditation scheme cannot be achieved.

Ovine pulmonary adenocarcinoma

Control of ovine pulmonary adenocarcinoma (jaagsiekte) is difficult due to the chronic nature of the disease and the high levels of virus shed by infected cases, and is therefore based on reducing levels of viral exposure to minimise spread. The box below describes how to reduce transmission in infected flocks.

Lung abscesses

Caseous lymphadenitis

Once present in a flock, caseous lymphadenitis (CLA) is controlled by the early detection, isolation and removal of confirmed cases. *Corynebacterium pseudotuberculosis* can survive for long periods in the environment and is not responsive to treatment. Regular examination of the flock for typical abscesses is important, particularly before shearing or dipping. Hygiene is essential, so handling pens, feed troughs and shearing equipment must be disinfected. Reducing the risk of wounds helps minimise the spread, and younger animals should be handled before the older flock to reduce the number of animals potentially exposed. A recently developed ELISA blood test may help with the diagnosis and control of CLA in infected flocks.

CLA vaccines, including autogenous vaccines, have been used in some flocks, and can be produced under a special licence from the Veterinary Medicines Directorate. In certain situations they may be imported from overseas under licence. There is no commercial vaccine for CLA currently available in the UK.

Tuberculosis

Reducing contact between sheep and cattle on farms where tuberculosis has been confirmed in cattle will minimise the risk of transmission. This includes avoiding shared grazing and avoiding shared airspace during housing.

Reducing transmission of jaagsiekte virus in infected flocks

- Segregate and slaughter suspect cases (ie, adult sheep with weight loss and respiratory signs) early. A jaagsiekte virus PCR test is currently undergoing validation to detect proviral DNA in animals during the preclinical and clinical stages
- Do not retain the offspring of infected sheep for flock replacements
- Minimise trough feeding and regularly disinfect troughs
- Reduce housing time and stocking density during housing to reduce spread and exposure
- Avoid intensive lamb rearing systems involving the housing of large groups of lambs, as this increases viral spread
- Separate the youngstock and house or graze away from older, potentially infected ewes
- Use embryo transfer with valuable animals
- Snatching lambs at birth and artificially rearing them has been used to develop a new 'clean' flock, although it is uncertain whether intrauterine transmission can occur. High levels of environmental contamination mean that lambs can be exposed to the virus at or soon after birth
- Prevent contact with goats, as ovine pulmonary adenocarcinoma has been reported in this species

Prompt culling of thin ewes, particularly those with concurrent respiratory signs, is an important part of controlling ovine pulmonary adenocarcinoma (jaagsiekte) in endemic flocks. Picture, Tim Jones

Tick pyaemia

Control of tick pyaemia is based on managing tick infestations and the underlying *Anaplasma phagocytophilum* (tickborne fever) infection. Methods of tick control include treatment with diazinon and pyrethroid topical preparations, and avoiding known tick pastures during peak tick infestation. This is particularly important for susceptible groups such as young lambs, naive animals and ewes in late pregnancy. A prophylactic intramuscular injection of long-acting oxytetracycline (200 mg/ml solution, at a dose rate of 20 mg/kg or 1 ml/kg) before exposure can also prevent disease.

UPPER RESPIRATORY TRACT DISEASE

The majority of upper respiratory tract infections involve a self-resolving, low-grade rhinitis, but some involve individual cases of foreign body reactions or occasionally tumours. Laryngeal chondritis and nasal myiasis are two conditions that can result in significant disease problems and specific treatment may be required.

LARYNGEAL CHONDRITIS

As the cause of laryngeal chondritis is unknown, this condition is difficult to prevent, although removal of dry feed may be advisable in flocks experiencing outbreaks. Care during handling and drenching are also sensible precautions, particularly in short-necked breeds.

Treatment

If initiated early enough, antimicrobial and corticosteroid treatment can be successful. A large dose of intravenous corticosteroids (not licensed for use in sheep and therefore used under the prescribing cascade) and a large dose of a broad-spectrum antimicrobial should be administered, with continued antimicrobial treatments at reduced doses for five to seven days.

In severely dyspnoeic cases, an emergency tracheostomy can be performed. The tracheostomy tube must be cleared twice a day initially, and then once a day after it is clear. After two to three weeks, the infection will hopefully have subsided and the tube can be removed. In non-resolved cases, surgery to remove the necrotic tissue from the larynx can be attempted.

Unfortunately, treatment is often unsuccessful as cases are usually only identified when there are pronounced clinical signs and therefore advanced laryngeal lesions. Inhalational pneumonia can also complicate some cases.

NASAL MYIASIS

Nasal myiasis is caused by the larvae of the *Oestrus ovis* fly, which inhabit the frontal, maxillary and nasal sinuses of sheep. Treatment is generally not necessary but may be required if high larval numbers are present or if clinical signs are problematic. This should ideally be carried out between December and February when the larvae are small, because killing mature larvae found in the sinuses at other times is thought to potentially result in inflammation of the sinus lining.

Effective treatments for nasal myiasis

- Ivermectin – injection and drench
- Doramectin
- Moxidectin – injection
- Closantel

SUMMARY

The effective control and treatment of respiratory disease in sheep in any flock should be based on the correct identification of causal factors and the infectious agents involved, and taken into account when formulating flock health plans. Identification of factors involved on an individual flock basis enables a structured approach to control and prevention, promoting health and welfare in the flock.

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References

ALIABADI, F. S., LANDONI, M. F. & LEES, P. (2003) Pharmacokinetics (PK), pharmacodynamics (PD) and PK–PD integration of danofloxacin in sheep biological fluids. *Antimicrobial Agents and Chemotherapy* **47**, 626-635

DAVIES, D. H., McCARTHY, A. R. & PENWARDEN, R. A. (1980) The effect of vaccination of lambs with live parainfluenza virus type 3 on pneumonia produced by parainfluenza virus type 3 and *Pasteurella haemolytica*. *New Zealand Veterinary Journal* **28**, 201-202

KELES, I., WOLDEHIWET, Z. & MURRAY, R. D. (1998) Vaccination with glutaraldehyde-fixed bovine respiratory syncytial virus (BRSV)-infected cells stimulates a better immune response in lambs than vaccination with heat-inactivated cell-free BRSV. *Vaccine* **16**, 1172-1178

LEHMKUHL, H. D. & CUTLIP, R. C. (1985) Protection from parainfluenza-3 virus and persistence of infectious bovine rhinotracheitis virus in sheep vaccinated with a modified live IBR–PI-3 vaccine. *Canadian Journal of Comparative Medicine* **49**, 58-62

McKELLAR, Q. A., GIBSON, F. I. & McCORMACK, Z. R. (1998) Pharmacokinetics and tissue disposition of danofloxacin in sheep. *Biopharmaceutics and Drug Disposition* **19**,123-129

MAVROGIANNI, V. S. & FTHENAKIS, G. C. (2005) Efficacy of difloxacin against respiratory infections of lambs. *Journal of Veterinary Pharmacology and Therapeutics* **28**, 325-328

PÁLFI, V. & BELÁK, S. (1980) Production and antigenic effect of experimental sheep adenovirus vaccines. *Acta Microbiologica Academiae Scientiarum Hungaricae* **27**, 135-139

RODGER, J. L. (1989) Parainfluenza-3 vaccination of sheep. *Veterinary Record* **125**, 453-456

WELLS, P. W., SHARP, J. M., RUSHTON, B., GILMOUR, N. J. L. & THOMPSON, D. A. (1978) The effect of vaccination with a parainfluenza type 3 virus on pneumonia resulting from infection with parainfluenza type 3 virus and *Pasteurella haemolytica*. *Journal of Comparative Pathology* **88**, 253-259

Further reading

BELL, S. (2008) Respiratory disease in sheep 1. Differential diagnosis and epidemiology. *In Practice* **30**, 200-207

CHRISTODOULOPOULOS, G. (2005) Maedi-visna: clinical review and short reference on the disease status in Mediterranean countries. Proceedings of the 6th International Sheep Veterinary Congress. Crete, Greece, June 17 to 21. pp 51-55

FONTAINE, M. C., BAIRD, G., CONNOR, K. M., RUDGE, K., SALES, J. & DONACHIE, W. (2006) Vaccination confers significant protection of sheep against infection with a virulent United Kingdom strain of *Corynebacterium pseudotuberculosis*. *Vaccine* **24**, 5986-5996

LINKLATER, K. A. & WATSON, G. A. (1983) Sheep housing and health. *Veterinary Record* **113**, 560-564

LLOYD, S. (1994) Caseous lymphadenitis in sheep and goats. *In Practice* **16**, 24-29

LLOYD, S. (1997) Caseous lymphadenitis in sheep and goats. In Sheep and Goat Practice 2. Eds M. Melling and M. Alder. London, W. B. Saunders. pp 185-196

MARTIN, W. B. & AITKEN, I. D. (Eds) (2000) Diseases of the respiratory system. In Diseases of Sheep, 3rd edn. Oxford, Blackwell Science. pp 177-204

RADOSTITS, O. M., GAY, C. C., BLOOD, D. C. & HINCHCLIFF, K. W. (2000a) Diseases caused by bacteria. In Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, 9th edn. London, W. B. Saunders. pp 852-855

RADOSTITS, O. M., GAY, C. C., BLOOD, D. C. & HINCHCLIFF, K. W. (2000b) Diseases caused by viruses and chlamydia. In Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, 9th edn. London, W. B. Saunders. pp 1184-1191

SWIFT, B. L., KIMBERLING, C. V. & JENSEN, R. (1987) Diseases of the respiratory system. In Jenson and Swift's Diseases of Sheep, 3rd edn. Philadelphia, Lea & Febiger. pp 173-181, 265-279

THONNEY, M. L., SMITH, M. C. & MATEESCU, R. G. (2002) Vaccination of ewes and lambs against parainfluenza 3 to prevent lamb pneumonia. Proceedings of the 8th Great Lakes Dairy Sheep Symposium. Cornell University, USA, November 7 to 9. pp 88-94

URQUHART, G. M., ARMOUR, J., DUNCAN, J. L., DUNN, A. M. & JENNINGS, F. W. (1996) Veterinary entomology. In Veterinary Parasitology, 2nd edn. Oxford, Blackwell Science. pp 163-164