Introduction

Infectious animal diseases cause major losses to livestock production. A significant number of them can easily be spread to humans e.g. as food-borne infections, and to wildlife. Infectious diseases are also a major cause of poor animal welfare. Within livestock production, it is too late to undertake actions only after clinical signs of disease have developed. Instead, a continuous focus on disease prevention is needed, which also minimises the need for use of antimicrobials and any subsequent risks of problems with antimicrobial resistance. The importance of prevention is emphasised in the new EU Community Animal Health Strategy, which has been named ‘Prevention is better than cure’ (DG SANCO, 2007). This chapter summarises the elements involved in the prevention and control of infectious diseases and principles and strategies for their use.

Categorisation of Diseases

For a structured approach, the wide panorama of existing diseases can be split into three major categories as shown in Figure 25.1. Figure 25.1 also indicates the major principles globally applied for their prevention and control.

The diseases belonging to each of the three categories (Figure 25.1) vary by country and region, but categorisation is traditionally based on the economic importance, prevalence and historical experiences of different diseases. The importance of the three groups of diseases is also reflected in the global and national legislation applied for their prevention and control (Figure 25.2).

International and national legislation and policies focus on the major epizootic diseases and increasingly also...
on the major food-borne zoonotic diseases. According to the legislation, the public compensation for outbreak control and surveillance is generally limited to specific epizootic diseases (e.g. Foot and Mouth Disease (FMD) and Classical Swine Fever (CSF) often referred to as ‘listed diseases’. The legislation and categorisation of the diseases is of crucial importance in determining whether there is public or private responsibility for interventions regarding specific diseases, as highlighted in the recent assessment of the EU animal health policy (DG SANCO, 2006). In general, producers are fully responsible for the prevention and control of the endemic diseases, as well as for the economic burden caused by these diseases. A concern for producers is that they are usually also given the responsibility for the control of the food-borne zoonoses (e.g. Salmonella and Campylobacter), despite those diseases seldom causing any significant clinical disorders or economic losses in animals (IAASTD, 2009). It should also be understood that in the developed countries most of the listed diseases have been eradicated or brought under strict control.

In view of the fact that there is no difference in principle between the methods available for the control of the three categories of diseases (Figure 25.1), experiences gained from the control of the listed diseases can successfully be applied e.g. to the endemic diseases and vice versa. In many developed countries a number of the endemic diseases have also been successfully eradicated or controlled by applying methods used for the listed diseases. Such programmes have been found to be very cost-effective (e.g. Valle et al., 2005). The increasing focus on animal welfare and antibiotic resistance further emphasises the importance of control of the endemic diseases (Angulo et al., 2004; OIE, 2005). The global burden of the whole panorama of infectious animal diseases, including the public health cost of human infections, is dominated by the endemic diseases, further emphasising their importance (Figure 25.3).

**Basic Requirements for Prevention and Control**

**Correct Diagnosis and Appropriate Scientific Skill**
All actions should be based on correct diagnosis. Basic clinical training and skill as well as access to qualified diagnostic laboratory services are therefore essential. In addition, the outline of a suitable strategy for disease-preventing health control and its implementation is specialist work that requires deep insights into veterinary pathology and microbiology and an understanding of the epidemiology and pathogenesis of the disease and of the situation associated socio-economic situation. These qualifications can be summarised under the term "epizootiology" or with "preventive veterinary medicine" which more includes also possible public health involvement.

**Recording of Disease Occurrence**
Control and prevention of animal diseases also require insights into disease occurrence. A system for the monitoring and surveillance of disease occurrence should therefore be established (Doherr and Audigé, 2001; Stärk et al., 2006). In health control at herd level, disease-recording systems can be based on observational results such as the recording of lesions at slaughter or production data such as weight gain, pregnancy and farrowing rate. Such data, despite often being of a non-aetiological type, are valuable tools as a basis for further evaluation of possible involvement of specific infectious diseases.
Concept for Prevention

Figure 25.4 shows the factors influencing the establishment of infections, which are used here for an analysis of available concepts for disease prevention and control.

Microbial Exposure
Prevention of infections can simply be achieved by protecting the target animal from exposure to infectious doses of the pathogenic microbe.

1. Total Exclusion from Exposure – Eradication
The most extreme and safest way to prevent an infectious disease is by eradication of the pathogenic microbe. This is usually applied for epizootic diseases in a country or on regional level. The requirement for an eradication procedure is that the epidemiology of the infection concerned is known. An eradication procedure has to be based upon good monitoring and surveillance systems and associated reliable diagnostic techniques and capacity that allow the identification of infected animals or holdings. Access to management and technical infrastructure is necessary to stop the spread of the infection and eliminating its source is essential. Of particular importance is consideration of the requirements for preventing re-introduction of the infection once eradication status has been achieved.
The diseases to be covered by an eradication policy are specified on both national and international levels on the basis of their economic importance and degree of contagiousness (Figures 25.1 and 26.2). Examples are FMD, CSF and Newcastle disease. The control and eradication procedures for this group of diseases have been worked out based upon the epidemiology and the properties of the causal agent for each of the diseases involved. The methods are today well-known both for outbreak control and for the eradication process, as well as prevention of re-introduction of the agent into an area that has achieved disease-free status. The importance of alertness is exemplified in the EU, where all member states must have detailed contingency plans in place against the epizootic diseases.

Scientifically, it is today possible and economically justifiable to control several non-listed diseases with the aim of eradication, even though they are currently not covered by legislation and associated reimbursement of associated costs. Examples of such diseases are Aujeszky’s disease in swine and Infectious Bovine Rhinotracheitis (IBR) in cattle, and also diseases with a more complicated epidemiology such as Bovine Virus Diarrhoea (BVD) in cattle. When monitoring demonstrates that herds or even regions or countries are free from such diseases, it is consequently justifiable to ensure that this status is maintained.

It must be noted that measures aiming at controlling and eradicating diseases are in a challenging conflict with the concept of free trade. Demands, e.g. pre-movement testing to prevent the spread of infections, are often considered as trade barriers, which therefore are continually being discussed e.g. within the EU and at OIE, WTO and CODEX on the international level. If these problems are not appropriately addressed, free international trade risks resulting in a situation where borders are unconditionally closed for certain trade or ambitions to improve animal health are discouraged. We may then end up in a situation where the lowest disease status of a participating country will be considered as the standard.

If eradication status cannot be achieved on a country level, it can perhaps be achieved on a regional or herd basis. As part of an organised health control scheme or quality control programme, individual herds and specified types of herds can achieve and maintain disease-free status for certain diseases. This is usually officially regulated for herds of special importance such as boar and bull stations, as well as hatcheries in poultry production. The reason is that infections in those holdings would easily result in a dramatic and fast spread of infections to a large number of herds.

SPF production in swine is a special form of production where total freedom from certain pathogens exists. The status is primarily obtained in animals delivered by caesarean section. These animals are then bred and housed in ordinary farms but under strict biosecurity. The system operates on a large-scale basis in e.g. Denmark and to a limited extent in other countries. The economic significance of infections excluded by this model is well exemplified by the growth rate in such pigs. When raised under SPF conditions, the slaughter weight of 110 kg is reached within approximately 150 days, compared with at least 180 days for conventionally reared pigs (Wallgren, 1994).

2. Partial Exclusion from Exposure – Prevention

This method should always be applied in animal production, at least for endemic infections. The concept is to minimise the microbial exposure to a level below the infective dose, or decrease it to such an extent that immunity is induced in exposed animals but no clinical disease develops. This allows possible further spread of the infectious agent from the primarily exposed animals to be limited to such an extent that secondary clinical outbreaks in contact animals are prevented. Methods empirically and/or scientifically found to promote this concept are:

**Optimising Hygiene**

The application of basic concepts of hygiene, which can be defined as measures taken to prevent sources of pathogens building up and methods applied for preventing their exposure to possible target animals. In animal production, this should primarily focus on preventing exposure to the manure. For example, Holmgren and Lundeheim (1994) found that piglets separated from their manure by e.g. cleaning, a drainable or slatted floor, or through well-handled straw bedding, were less susceptible to infections, with subsequent less need for antibiotic therapy. This is typically also found for poultry production.

**Isolating Sick Animals**

The isolation of sick animals is a basic measure for limiting the exposure of excreted pathogens to neighbouring
animals in a herd. Sick animals excrete large amounts of infectious doses. For example, a Salmonella Dublin-infected calf is reported to excrete up to 100 (LD 25) infectious doses per gram of faeces (Wierup, 1983). It should then easily be understood that the isolation of such an animal may well be the threshold that prevents an isolated outbreak of salmonellosis in one or a few animals ending up in an enzootic spread of the infection within a herd.

**Avoiding Introducing Sick Animals into a Herd**
For the same reason as sick animals should be isolated, they should not be traded or introduced into other herds. Transport itself is known to be a factor that can trigger the exacerbation of a subclinical infection to fulminant status and associated excretion of the pathogen (Isacason et al., 1997). A simple recommendation is therefore to isolate new animals for at least an incubation period before they are introduced into a herd. This allows clinical observation and, when required, testing for specific infections. A general recommendation is that animals should be introduced into a herd only if they come from herds of the same or higher health status, usually verified through being linked to specified health controls and associated biosecurity measures.

**Replacing Live Breeding Animals by Semen and Embryos**
The genetic status of a herd has traditionally been improved through importation of live breeding animals. In most countries this method has historically led to the introduction of a number of economically devastating diseases. In Sweden, the importation of Friesian bulls in the 17th century resulted in the introduction of e.g. bovine tuberculosis, which subsequently reached a mean national prevalence of 30% of slaughtered animals when diagnosed only by meat inspection, before eradication efforts started. Even if the risk for introduction of epizootic diseases has decreased as a result of international cooperation, this is not the case for the endemic diseases. However, this risk is considerably decreased when the importation of live animals is replaced by semen and embryos.

**Using Antimicrobials**
The use of antimicrobials is usually considered the method of choice to combat and decrease the number of pathogens. However, the associated risks and problems due to antibiotic resistance have highlighted the need for a change in attitude. In different countries, official or industry-based guidelines have therefore been worked out for such a use in order to contain antibiotic resistance. It cannot be overemphasised that the use of antimicrobials should be based upon a diagnosis following a clinical, and when relevant also a bacteriological, examination. Even if this demand in the real-life situation cannot be fulfilled before therapy is started in all individual cases, different forms of disease monitoring should be performed to limit the use of antimicrobials to cases and situations when bacterial infection is the problem.

The antibiotic resistance pattern should also be checked regularly using relevant methods. It is necessary to determine that the bacteria causing the infection is sensitive to the antibiotic to be used. The dose, way of administration and duration of the therapy should be according to recommendations formulated by the manufacturer, as approved by the relevant authority. As a final step, it is important to follow up and document the clinical results of the therapy, in fact a documentation of the real-life situation.

Although not implemented in all countries, a generally accepted recommendation is that antimicrobials should only be used following a veterinary prescription. In addition, strategies and rules should be established to minimise the risk of a positive economic incentive for veterinary surgeons to prescribe antimicrobials.

The use of antimicrobials for growth promotion should be terminated, as discussed in chapter 28. The use of antimicrobials also be monitored. This is necessary for an evaluation of the antibiotic resistance pattern in relation to the use of antimicrobials and for the formulation of associated recommendations on their use. In the absence of such data, it is not possible to verify compliance with given recommendations and regulations. Efforts should also focus on the education of producers/farmers in the proper use of antimicrobials.

**Host Resistance**

**General Resistance**
To maintain the optimal physiological resistance of a healthy animal, a series of factors have to be fulfilled. The nutritional needs of the animal have to be satisfied. Deficiencies or excesses in proteins, vitamins and trace elements, as well as imbalanced feed composition, can
easily result in outbreaks of disease and a decreased capacity of the immune system.

Animal rearing and housing are also essential and ventilation and temperature are well-known factors of importance in this respect. Correction of the ventilation often considerably improves the health status in relation to respiratory diseases in e.g. fattening pigs. When antimicrobial growth promoters (AGP) were banned in Sweden, it was found that the ventilation in the broiler houses often was under-dimensioned, resulting in clinical problems with e.g. necrotising enteritis during periods with hot outside temperatures (Wierup, 1999). Temperature is another factor, and e.g. in temperate climates additional heating prevents diarrhoea both in new-born piglets and weaners, and is also a necessity for newly hatched chicks (Wathes et al., 1989).

Management routines that allow normal behaviour and wellbeing are also essential. A basic requirement is to avoid different forms of stress. This is exemplified in pig production, where the loose sow system in wrongly designed pens in relation to feeding and the social grouping of the sows may easily lead to fighting, with severe secondary injuries and under-nutrition in low-ranked animals (Edwards, 1992).

Specific Immunity

Through the use of vaccines, the immune system can be used to control specific infections and many infections can be effectively prevented in this way. The clostridial infections in ruminants are a typical example and another is vaccination against piglet diarrhoea, which has practically replaced the previous substantial use of antibiotics to control this disease (Söderlind et al., 1982). A more recent example is vaccination against vibrio infections in fish farming (Markestad and Grave, 1997).

Control and eradication of immunodeficient diseases such as BVD, Bovine leucosis in bovines, CAE in goats, Maedi Visna in sheep and Infectious Bursal Disease in poultry, as well as Aujeszky’s disease in pigs, have significant health-supporting effects beyond the direct losses due to the absence of clinical disease caused by those diseases.

The disease preventive effect of maternal immunity reflects the infections that the mother has experienced. Older animals therefore generally provide better maternal immunity to their offspring than younger. This was observed at an early stage e.g. in Denmark, where infectious diseases were more frequently found in piglets from gilts and young sows compared with piglets from older sows (Nielsen et al., 1976). The age profile of a herd is therefore of importance, and too high a recruitment rate may have a negative effect on the health situation.

Combinations

The principles described above can be used as single actions. However, as a rule the production systems of animal husbandry usually combine several principles in order to optimise the disease-preventing effect. In the following, this is exemplified mainly from pig production.

The all-in, all-out concept prevents the spread of infections between consecutive groups of animals raised in the same unit. This is practised in the production of most animal species raised for meat production, such as fattening pigs and broilers. A typical violation of that strategy is to keep slow-growing animals in a batch in the same unit until they reach appropriate slaughter weight and simultaneously bring in a new batch of young animals. The latter then easily become infected by those pathogens that are usually the cause of the growth retardation in the slow-growing animals.

The all-in, all-out production system also facilitates cleaning and disinfection between batches, which is a further step to minimise the spread of pathogens from older growing animals to new and younger ones. The all-in, all-out system, with careful cleaning and disinfection, has long been essential in broiler production, aiming at control of salmonella and campylobacter (Berndtson, 1996; Wierup and Wegener, 2006), and such systems are now generally the standard routine in beef and swine production too. Violation of these procedures empirically often results in break-downs of the health status.

A further development of this concept is age-segregated batch production, in which is an all-in, all-out system with groups of animals of the same age. The groups can be kept separate on the same farm, on-site, or at a separate holding off-site. The distance between holdings is of special importance for the spread by wind of respiratory infections. The distance from an SPF swine herd to other holdings of swine is therefore recommended to be at least 0.5-1.0 km.
In pig production, sows are now frequently managed so that they all farrow within a few days. The piglets from these sows are kept together and separated from other animals until slaughter, which also includes the ambition to keep each litter together. In Sweden this type of production was found to be of basic importance to overcome clinical problems when the use of AGP was banned in 1986 (Holmgren and Lundheim, 1994; Wierup, 2001).

Sow pool production is a special form of multi-site production in which sows are mated and housed at one production site, a pool, and then transported in batches for farrowing on separate farms (satellites). At those satellites the piglets are reared until slaughter, while the sows are transported back for breeding at the pool after weaning of their piglets (Holmgren and Gerth-Löfstedt, 1992).

The importance of the above systems was reflected early in the growth rate obtained. The daily weight gain in slaughter pigs (30 kg to slaughter) in SPF production is often > 1 kg, compared with 0.85 kg in corresponding conventional continuous production. However, in the satellites of sow pools, a 1 kg daily weight gain can often be obtained (Wallgren, 1994). The economic significance of these differences is obvious.

The significance of the measures exemplified above can be better understood when considering that most infectious diseases, although caused by one specific microbe, usually primarily have a multifactorial course. Thus all factors decreasing the risk of an infection becoming established will contribute to improving the health situation in individual animals and on a herd basis.

It is also interesting to note that the probability of infection becoming established in susceptible animals when exposed to infected animals is usually far less than 1. In relation to Aujeszky’s disease, it was demonstrated in a swine herd that in spite of frequent direct contacts with ADV-infected pigs for up to 1 year, no spread of infection occurred in exposed non ADV-infected animals (Engel et al., 1995). In Denmark, it was also found that the spread of PRRS infection into herds by semen from PRRS-infected boars was recorded only in 7 out of 700 herds tested (Mortensen, 1998).

The control of salmonella in animal production in Sweden constitutes a good example of how the long-term and consistent application of the preventative measures described above has reduced the prevalence of this infection to a negligible level (Wierup, 2008).

**Disease Prevention in Wildlife**

The control of infectious diseases in wildlife involves substantial challenges compared with their control in domestic animals. However, when possible, fruitful efforts have been made primarily to protect human health against zoonoses in wildlife (e.g. rabies) or to prevent diseases in the wildlife from being transmitted to food-producing animals (e.g. classical swine fever and *Brucella suis*). A third aim is to protect wildlife from certain destructive diseases, e.g. bovine tuberculosis, that can threaten the existence of certain wild animal species in animal parks and zoos (e.g. Michel et al., 2003). This presentation is limited to the control of two different types of diseases (rabies and CSF) as examples of the challenges involved. Other diseases in wildlife that pose a significant threat to the livestock production are bovine tuberculosis (bTB), where e.g. infections in badgers have been found to spread to cattle, which can prevent the eradication of bTB from the cattle population in England and Ireland. The currently increasing wild boar population also poses a risk of reintroducing *Brucella suis* to the domestic swine production (EFSA, 2009:2). The vector-borne diseases, which are of increasing importance in relation to climate change, are dealt with in chapter 23.

**Rabies**

Starting 1940s, an epizootic of fox rabies spread westwards from Poland, with a 20-60 km advance per year, resulting in the infection of several European countries. The most westerly point of spread in France was reached in 1982, and a peak of more than 4,200 rabid animals was recorded in 1989. Eighty-three percent of the reported cases were in red foxes (*Vulpes vulpes*), which are the main reservoir as well as the main vector of the virus (Aubert, 1995).

Oral vaccination campaigns have resulted in a drastic decrease in the incidence of rabies in most western European countries. In Finland, which in 1988 experienced an outbreak of rabies in raccoon dogs and foxes,
field vaccination using two bait-layings a year was successfully applied, and since 1991 a single bait-laying each year in autumn has sufficed (Finnegan et al., 2002).

The vaccination has to be performed in organised campaigns and the strategy, including the interval between vaccinations and the duration of the campaign, need to be modified to the regional situation and the vectors involved. In Germany, vaccination has resulted in a drastic drop in rabies incidence but severe set-backs have occurred in some areas. There is always a risk of re-infection from infected surrounding areas when vaccination is stopped and the creation of an immunological barrier to such areas is usually required.

Successful vaccination campaigns have also been performed in Canada and in the USA. Beginning in the 1990s, coordinated oral vaccination campaigns were implemented in Texas to contain and eliminate variants of rabies virus in grey fox (*Urocyon cinereoargenteus*) and coyote (*Canis latrans*), and in several eastern US States with the goal of preventing the spread of rabies in raccoon (*Procyon lotor*). The primary components of the control strategy include: enhanced rabies surveillance, coordinated vaccination, use of natural barriers, and contingency actions to treat emerging foci.

The National Rabies Management Program, which is a cooperative programme that began in 1997, has progressively grown to meet rabies control needs and currently includes oral vaccination in 16 eastern states and Texas and Arizona. Approximately 11 million baits are distributed annually over about 200,000 km² in strategic locations to contain and eliminate variants of the rabies virus in coyotes, grey foxes and raccoons. However, the existence of different vector animals is challenging. Skunks appear to help maintain the raccoon variant and serve to re-infect areas (Guerra et al., 2003), potentially confounding the ability to achieve long-term rabies management goals with currently available tools (Slate et al., 2005).

On the other hand, the control of rabies in bats poses other challenges which so far cannot be met by organised preventative actions. A limiting factor is that many bat species are protected. In Europe there is a cycle of insectivorous bat rabies (European bat lyssaviruses; EBLs) which is independent from the epidemiological rabies cycle that involves foxes and other terrestrial mammals.

**Classical Swine Fever (CSF)**

CSF has caused major outbreaks in the EU during recent decades and a major threat of new epidemic exists due to the fact that CSF virus is present in the wild boar population. The infection is spread by direct contact between wild boar and pigs and indirectly mainly due to the release of contaminated meat products in the environment (Artois et al., 2002).

Wild boar populate most European forests, even in wetlands or mountainous areas (Acevedo et al., 2006). This potential threat is increasing, since the size and range of European populations has critically increased over the past 30 years, possibly due to changes in the hunting practices, the expansion of single-crop farming and climate warming.

During 2003-2007, CSF was reported in Germany, France, Luxembourg, Belgium, Slovakia, Romania, Bulgaria and many other European countries such as the Balkan states and Russia (EFSA, 2009).

In order to prevent outbreaks of CSF in domestic animal production, measures are being undertaken to reduce the contacts between pigs and wild boar, e.g. through the education of hunters and farmers regarding swill feeding and evisceration in forests and the use of electric fences for open-air farming that will prevent physical contact between wild and domestic animals. In addition, significant attempts are being undertaken to stop the natural spread of the disease among wild populations.

Theoretically, eradication in the wild boar population can be achieved by decreasing the number of susceptible individuals in the population to under a threshold level that decreases the probability of the virus surviving. However, in the absence of tools for exhaustive culling and the vaccination of a well-controlled population, as in the domestic situation, the eradication of CSF in wild populations is a complicated issue. The available and applicable current tools are hunting and vaccination. Hunting is performed by amateurs and may negatively influence the population dynamics and, like vaccination, cannot be exhaustive or homogeneous. As it is now known that the spread of CSF in the wild boar population in practice cannot be stopped by hunting, substantial efforts have been made in the EU to control it by the use of vaccine (EFSA, 2009).

Oral vaccination of feral pigs has been used by several EU member states to control the disease. The vaccine
used is attenuated C-strain in liquid form (Chenut et al., 1999) and is incorporated into strong-smelling baits that are attractive to wild boar (Kaden et al., 2000). Baits are distributed either by hand at feeding places or by aeroplane. Field trials in Germany and France have confirmed the positive effect of vaccination in controlling CSF outbreaks in wild boar populations (Kaden et al., 2005).

Besides vaccination in infected areas, immunisation has been carried out in a zone surrounding that area. The concept of this so-called ‘cordon sanitaire’ is to build up a vaccination barrier to a non-infected area to stop the further spread of the disease to unaffected territories.

The main limitation of oral vaccination in wild boar relates to bait consumption in the youngest age classes and in practice the direct impact of oral vaccination is restricted to animals older than 3 months. However, due to the transfer of colostral immunity, vaccination of older sows has an indirect effect on the immune status of the offspring.

The main effect of vaccination is to maintain a high level of herd immunity, which prevents the spread of the virus. Thus vaccination of an infected population can be considered a valuable tool to control and possibly eradicate the infection from an area (e.g. Von Rüden, 2008).

Conclusions

The control of infectious diseases in livestock involves numerous strategies, of which the use of antibiotics is one. The intelligent use of the wide panorama of available disease preventive measures, as exemplified above, can easily contribute to a good health situation and improve the economics of animal production without the use of antibiotics except for treatment of sick animals. On the other hand, when a bacterial infection is established, antibiotic therapy is an effective first method of choice and should be used to prevent suffering in sick animals. Antibiotics are probably the most valuable drugs in animal production and the use of antibiotics should thus be considered as an integral and usually final part of the disease prevention strategy. They should be used when all other measures have failed, and not as a replacement for them. A production system that requires the routine use of antibiotics for all animals is not sustainable and cannot be recommended due to reasons further described in the subsequent chapter 29.

The control of infectious diseases in wildlife involves substantial challenges. However, fruitful efforts have been made primarily to protect human health against zoonoses in wildlife (e.g. rabies) or to prevent diseases in the wildlife from being transmitted to food-producing animals (e.g. classical swine fever and Brucella suis). A third aim is to protect wildlife from certain destructive diseases, e.g. bovine tuberculosis, that can threaten the existence of certain wild animal species in animal parks and zoos.
Chapter 25


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Chapter 26


Chapter 27


